JUL 22 1935

INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT AND CONTROL

Volume 8 JULY 1935 Number 7

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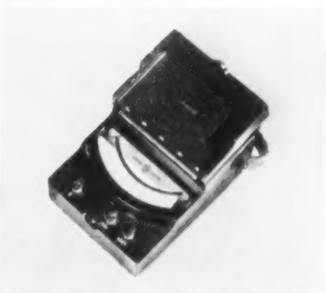

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EDITORIAL COMMENT

In This Issue

Microcinematography combines the microscope and the motion-picture camera. Henry Roger, the first successful combiner, discusses the technique and describes two outfits he designed: one the Rolls-Royce and the other the Forvrolymouth of this branch of Instrumentation.

All *Instruments* readers use lubricants; nearly all are occasionally faced with the problem of specifying a lubricant—and discover that some lubricating experts disagree as sharply as do medical experts. H. Hunter Smith, an impartial investigator helping to change the art to a science, discusses some properties of lubricants and describes a promising new type of viscometer.

Full of promise, too, is the method described by Professor Eddy and his associates: using a standardized wire for controlling furnace temperature *and heating-rate*. Their article not only describes the new apparatus but presents an analysis of furnace control which will interest metallurgists, ceramists and many others.

"True-direction" aircraft instrument ideas are discussed by J. A. Brooks (a pioneer worker in this field—see page 111 of the May issue) and by L. A. Widmark who likewise knows his electricity and mathematics.

This month's instalment of our electrical measurements serial concludes the subject of demand meters and discusses other special meters—all familiar to Perry A. Borden.

A new serial starts in the "Inspection and Testing" department (see our main editorial alongside). It covers *cathode-ray* oscillographs, whereas V. S. Thomander and Paul MacGahan make a brief but comprehensive survey of the field of *electromagnetic* oscillography. The two fields overlap almost completely but each class of instrument has its logical uses—which brings to mind that nearly every kind of measurement problem can be solved by instruments of various classes: for example mercurial thermometry and resistance thermometry.

The same applies to control problems, as readers know who study the "New Instruments" department month after month. This month's is no exception: the controllers described therein are not for heretofore-uncontrollable conditions but are designed to provide new modes of control.

The front cover photograph shows the switchboard at the Bridgewater State Farm of the Commonwealth of Massachusetts, consisting of a swinging bracket and ten cubicles, generator voltage regulator, totalizers and feeder. Everything on the front is dead; sides and back are enclosed. All instruments, oil circuit breakers and instrument control switches are Roller-Smith.

The Inspection and Testing title page photograph shows J. Heinicke who has charge of the finishing room precision optics department at Bausch & Lomb. He is checking the wear on Johansson gage blocks by means of an optical flat. The inset shows how interference fringes look to an inspector.

Oscillography

MORE than fifteen hundred oscillographs sold in less than a year . . . This refers to only one type—the cathode-ray—and to a single firm's sales! One has to guess at the total number of all types and of all makes that were bought by research workers, engineers and production chiefs in this last year of the so-called industrial depression.

Many of us oldsters only remember our college lab oscillograph as the fearfully complicated subject of one group exercise, each member of the group being kept too busy to watch what the others did. As we later earned our daily bread in industry's service, few of us had occasion to use oscillographs before the First World War, and we were but dimly conscious of their slow improvement.

In the last twenty years this improvement has accelerated, together with increases in number of applications and in volume of sales. These increases have been nearly parallel. Their composite is a growth curve—an "S" curve. It evidently will cross the "1935" ordinate with a slope far greater than that of any antecedent portion, but its point of inflection cannot yet be plotted. Wherefore, midsummer 1935 would seem to be the ideal time for *Instruments* to push ahead this point of inflection. In other words, now is the right time to start publishing a series of articles which will not only satisfy the existing interest in oscillography but arouse a still greater interest.

Now is the right time; *Instruments* is the right medium; Ralph R. Batcher is the right author. A native of the corn belt (Dysart, Iowa, 1897) he was one of the earliest radio amateurs (1909) and operated station 9YI in 1915-1916 at Iowa State College, where he obtained his E.E. in 1920 after having served as radio instructor during the war. Connections with the Western Electric, Grebe and Decatur companies (as vice-president of the latter) added the practical industrial viewpoint to his scientific bent. In recent years he has been a Member of the Board of Editors of the I.R.E. and a consultant in electronic devices and applications. Having done much research on cathode-ray apparatus since 1914, he has been able to perfect numerous devices in this field.

M. F. BEHAR

Microcinematography

By HENRY ROGER*

Fig. 1. "The smallest things ever filmed"—motion picture of particles (0.01μ) in Brownian movement, taken at 20 images per second.

Fig. 2. Sarcoma fibroblasts (cancer cells).

Fig. 3. Front part of a single cell of muscle tissue.

IT IS a fact unknown to the average "movie" patron but well-known to workers in many fields, that the motion picture originated in the physiological research laboratory. Muybridge in America and Marey in France developed—almost at the same time, some 50 years ago—cameras for taking consecutive pictures of living objects, such as walking and jumping men, galloping horses, etc., in order to study their motions more carefully and more exactly than is possible with the human eye. Many facts have since been revealed with the aid of motion photography which were not observed or even suspected before its advent. Two factors make the motion picture camera an excellent tool of research:

1. The motion picture has made us the masters over the element of time. Events which are too fast or too slow for the human eye to perceive can, with its aid, be translated into understandable speeds. We are able today to follow with ease the flight of a bullet fired from a gun, photographed at the rate of thousands of images per second and slowed down on the screen. On the other hand we can follow the growth of a plant by speeded-up motion pictures: single photographs taken at comparatively long intervals — minutes, hours or even days — and projected in short succession, generally 16 per second (silent motion pictures). Time lapse motion pictures, as these are called, are today employed to solve a variety of research problems. Microscopic research in particular has profited greatly by time lapse photography.

2. The other factor which should here be mentioned and which is of great importance to research workers is the sensitivity of photographic emulsions to radiations extending far into regions beyond the ends of the visible spectrum. Thereby we are able to render visible such things as, for instance, structural details in the bodies of minute cells, which otherwise cannot be seen. We are able also to increase the values of contrast by photographic means and so bring out the delicate outlines of living cells at high magnifications.

The history of the microscope, and many of its varied possibilities, are too well known to *Instruments* readers to be summarized here.

Microcinematography is the union of the motion picture and of the microscope. It is still in its infancy but the results already obtained foreshadow ever-widening fields of application. So far, the greatest advances have been made in the biological sciences, especially in medical research. The author, during the many years of his association with Dr. Alexis Carrel at the Rockefeller Institute for Medical Research, had the opportunity to take and demonstrate many micro films of living cells of blood and tissue, and of bacteria, before scientific gatherings here and abroad. These films not only made many acquainted with the structure and the activities of cell life (of man, animals and plants) but they revealed new facts about cell behavior and cell structure. For instance, an undulating membrane surrounding white blood corpuscles was thereby discovered.

Since the first showings of these films of living cells, many investigators began to use the motion picture camera for their particular microscopic problems and today one frequently sees at scientific meetings new and interesting motion pictures of microscopic material.

There is practically no limit to the application of microcinematography not only in the biological sciences but also in chemistry, physics and the industrial sciences.

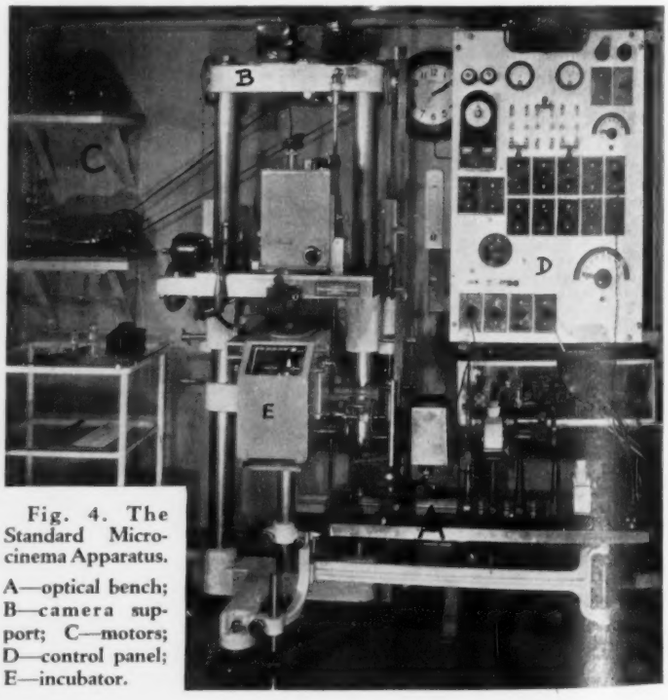


Fig. 4. The Standard Microcinema Apparatus.

A—optical bench; B—camera support; C—motors; D—control panel; E—incubator.

*President, Rolab Photo-Science Laboratories, Sandy Hook, Conn.

A number of such films have been demonstrated at "A Century of Progress" in Chicago. Lately an interesting film has been produced on "Colloids" with demonstrations of the Brownian movement of ultramicroscopic particles. Micro films have been adduced as evidence in legal procedures, especially in patent infringement cases. Applications abound also in the metallurgical and food industries. The list on this page has been compiled with the readers of *Instruments* in mind.

Mention must be made of the usefulness of micro films for mere demonstration. This becomes obvious when one considers how few people ever have the opportunity of looking through a microscope. Only through the motion picture can moving microscopic material be demonstrated to an audience of any size and without the otherwise necessary cumbersome preparations which precede practical demonstrations (micro projection).

TECHNIQUE

In principle, an apparatus for taking micro motion pictures resembles one used for (still) photomicrography, the only difference being in the camera. However, one soon finds many additional factors to be considered in microcinema work which do not enter the field of ordinary photomicrography. Let us begin with the latter: The material to be photographed is mostly inactive or dead. It is often stained or otherwise prepared in such a way as to bring out structural details. Practically all preparations are mounted on standard slides with cover-glass in a medium specially selected with regard to optical requirements (refractive indices). Since all optical parts of the microscope, the substage condenser, the objective, and the ocular, are designed for use with these standard slide mountings there are no particular optical problems involved. The length of exposure can be varied to a great extent, permitting the use of contrast or color-absorption filters, as any amount of light intensity can be employed. On the other hand, the material for microcinema work is *active* and its preparation and maintenance during the experiment require many precautions. For the preparation of living cells of tissue and blood a special technique had to be developed in order to keep these cells alive and free from bacterial infections during the time required for taking the film records. In most cases special glass vessels replace the standard glass slide mountings in order to maintain conditions as natural to the object as practically possible and also to permit experimentations. Unfortunately the use of these special glass vessels makes it impossible to obtain the optical conditions necessary for the resolution of details at high magnification, chiefly because of the presence of air below the object and also because of imbedding of the object in a medium not particularly adapted for the use of high-powered immersion lenses.

All living material is extremely delicate and extremely sensitive to light and heat. Excess of either means death to a cell. In microcinema work light intensities, necessary for correct exposures, vary to a great extent depending upon the frequency of images per second, per minute or per hour, and also upon the magnification, the color

(Continued on page 195)

SOME APPLICATIONS OF MICROCINEMATOGRAPHY

In Industry: refrigeration, fermentation and other processes; durability of various metals, paints, etc., under various conditions; corrosion; crystallography; action of detergents; oil sands; fuel research, etc.

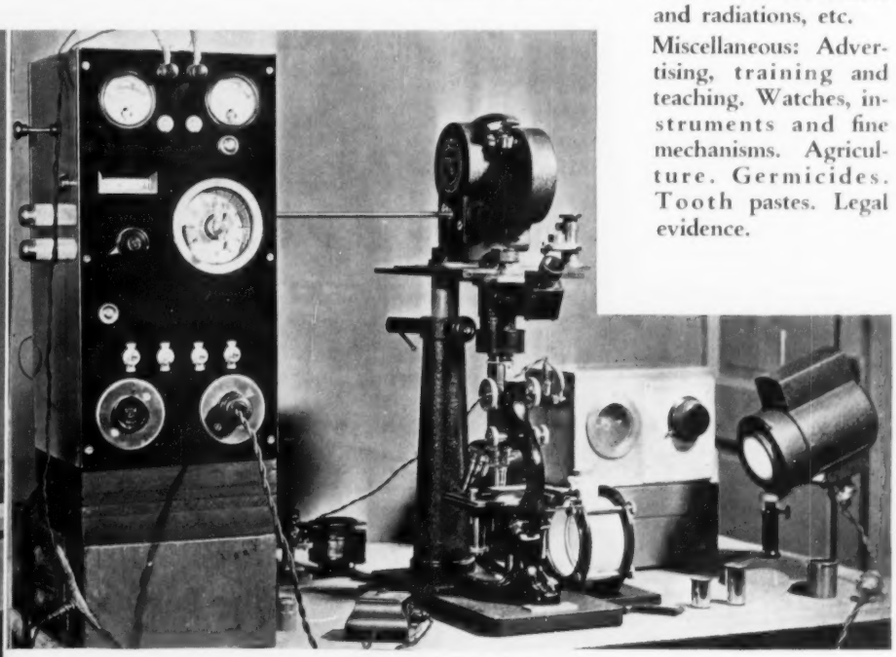
Food Industries: packing, canning, beer, milk, cheese, baking, etc.

Chemical and Physical Research and Demonstrations: absorption, precipitation, coagulation, cataphoresis, osmosis, colloids, magnetism, etc.

Biology: growth of cell colonies, division and phagocytosis, cell behavior, cell structure, influence on cells of various substances and various radiations (X-ray, ultra-violet, radium, short-wave, etc.), cell dissection, etc.

Bacteriology: study of colonies and single bacteria, bacteriophage, action of substances and radiations, etc.

Miscellaneous: Advertising, training and teaching. Watches, instruments and fine mechanisms. Agriculture. Germicides. Tooth pastes. Legal evidence.



MICROCINEMA APPARATUS FOR 16-mm. CAMERAS

Fig. 5 (left). Stand shown swung 180° for macro photography.

Fig. 6 (above). Outfit including control panel and other accessories.

Effects of Carbon Suspensions on Some Properties of a Lubricating Oil

By H. HUNTER SMITH*

INTRODUCTION

RAPID increase in the use of lubricating oils within recent years has led investigators to seek all of the scientific elements or properties which, when brought together, will give a lubricant that quality necessary for its particular application in the commercial world.

Pressure, speed, working temperature, conditions of the bearings and method of oil feed are some of the factors which determine the most advantageous oil to use. High pressure will produce a high viscosity as it tends to squeeze the oil from between the two surfaces. High speed will give a low viscosity because the fast-moving part pulls in more oil between the friction surfaces. High temperatures reduce the viscosity and for this reason hot bearings require oil of greater viscosity to maintain a film and thus prevent the two surfaces from rubbing together. With a circulatory oil feed or force feed, oils of lower viscosity can be used because of the increased amount of oil reaching the bearings.

Few measurements were made prior to 1842 from which the fundamental laws of fluid motion could be established. The name of Poiseuille is always associated with the laws concerning the simple nature of flow in capillary tubes, while the name of Osborne Reynolds is generally connected with the laws governing the complex conditions of flow in pipes and larger conduits.

Various ways of explaining the high viscosity of colloidal solutions and emulsions compared with the viscosity of the dispersive media were worked out by J. W. McBain.[1] Small additions of highly dispersed graphite, talcum and soap were shown to raise the viscosity of lubricating oils (Voltol oil an exception: its viscosity was lowered) in experiments performed by W. Ostwald and A. Fohre.[2] Effects of the addition of colloidal graphite to ordinary lubricants have been described in technical bulletins by the Acheson Oildag Co.

The field of force which exists at the free face of a solid or liquid is due to the unbalanced attractions of the molecules. Greasy films are formed on solid surfaces because they reduce the potential of the fields of attraction, and this process of condensation of foreign matter onto a surface is called adsorption. A lubricant may therefore be said to be adsorbed by solid faces and the greater the work done by these forces in forming the layer the better the lubricant.[3]

These facts bring to light the question of the importance of "oiliness" in lubrication. It was maintained that the fatty oils possessed greater "oiliness," "body," or lubricating value. The problem was to measure this property called "oiliness." Since the advent of the aeroplane the question of "oiliness" has become vitally important. It may be that a great deal of evidence on this point can be obtained from the cutting lubricants.

The present research has been undertaken in order to (1) determine the viscosity of oil at different concentrations of suspended carbon and (2) to establish, if possible, some definite relationships between viscosity and other properties in connection with an increase in concentration of these suspensions.

PRELIMINARY EXPERIMENTS

In order to determine suitable *suspension concentrations* several preliminary experiments were performed. Test-tubes of oil varying in concentration of suspended lamp-black were allowed to settle out as far as possible.

In spite of its title, Mr. Smith's article is essentially a description of a new method of measuring viscosity. But —and this is important—his purpose was not so much to devise a new viscosimetric method as to establish "oiliness" or "body" on a quantitative basis. He employs an old principle—counting the drops that issue in a given time from an orifice—but he has modernized it by adopting standard conditions, especially in maintaining a constant head; also by substituting a photoelectric counter for the familiar manual-tally counter. —M. F. BEHAR

This was done in order to determine if there was a definite percentage for complete saturation. It was found that after a certain concentration was reached the carbon settled out much faster than those suspensions containing less carbon.

It was necessary to make a number of preliminary experiments to find the most desirable *capillary tube for the viscosity determinations.* From these experiments a tube of uniform bore and 1.494 mm. diameter was selected. However, the apparatus was constructed so that tubes of different diameters could be used. It was found that if much more than 2.3 g. of lamp-black were placed in 250 cc. of oil the flow would be so slow that too much time was required for the readings and sometimes the capillary would become clogged.

A number of suspensions were made up and readings recorded. Some of these contained too much carbon while some did not contain enough to give a sufficient difference in the time of flow. It was learned from these experiments that the suspension concentrations listed in the table below would give the best results.

No.	*Weight of lamp-black in grams per 250 cc. of oil*	*Second series which was of slightly different oil and kind of lamp-black, contained the following amount of lamp-black:*
1	0.400	0.416
2	0.800	0.814
3	1.200	1.200
4	1.600	1.618
5	2.000	2.007
6	2.400	2.402
7	2.800	2.802
8	3.200	3.201

For example, concentration No. 1 of the first series was a suspension of 0.400 g. of lamp-black in 250 c.c. of Mobiloil Arctic oil. No. 8 was the strongest of the concentrations. Clear Mobiloil Arctic oil was also used.

*Fayerweather Laboratory of Physics, Amherst College, Amherst, Mass.

1J. W. McBain. Apparent Viscosity of Colloidal Solutions and a Theory of Neutral Colloids as Solvated Miscelles Capable of Aggregation. *Journal of Physical Chemistry*, Vol. 30, 1926, pages 239-247.

2W. Ostwald and A. Föhre. Viscometry of Lubricating Oils. *Kolloid-Zeitschrift*, Vol. 45, pages 166-177, June, and pp. 266-279, July, 1928.

3(a) W. B. Hardy and Lt. J. K. Hardy. Note on Static Friction and on the Lubricating Properties of Certain Chemical Substances. *London, Edinburgh and Dublin Philosophical Magazine*, Vol. 38, 6th Series, July 1919, pages 32-48.

(b) W. B. Hardy. The Spreading of Fluids on Glass. *Philosophical Magazine*, Vol. 38, July 1919, pages 49-55.

(c) W. B. Hardy, Static Friction. *Philosophical Magazine*, Vol. 40, July 1920, pages 201-210.

DESCRIPTION OF APPARATUS

It was necessary to control the factors which would vary the rate of flow through the capillary tube, namely, temperature and pressure. The temperature was controlled, simply, by the use of a large temperature bath (*B*, Fig. A). Flasks containing the different concentrations and clear oil were placed in the large bath which surrounded the glass viscometer. This entire system was held at a constant temperature throughout a set of readings. The pressure was controlled by making use of the principle of Mariotte's bottle. Referring to Fig. B (a photograph of the glass instrument which was carefully made by E. Machlett and Son), it is seen that when the instrument is in an upright position the flow of oil out through the end of the capillary will draw in more air through the central stop cock in order to maintain constant pressure. Note that capillaries of different diameters can be fitted in the ground end of the apparatus.

Having constructed the apparatus so that constant temperature and pressure were possible, it was only necessary to measure the time, weight and number of drops for determining absolute viscosity and relative surface tension.

In order to count the number of drops a photoelectric cell *P* was used. A lens *F* was used to bring the beam of light from the source *L* to a focus on the oil drops as they issued from the orifice *O*. See Fig. C. The magnetic counter *M* was connected to the relay of the "electric eye" for registering the total number of drops.

This type of viscometer is proposed by the author for commercial use because of its accuracy and convenience in use. In using this apparatus for relative viscosity tests it is necessary to measure only the time of flow of a certain number of drops while the number of drops is conveniently recorded by the photoelectric counter. This eliminates the necessity of measuring volumes or weights and also eliminates the tedious process of cleaning containers.

The elimination of measured volumes or weights in relative viscosity determinations with this instrument depends upon the fact that the weight per drop of a particular "grade" of oil is constant.

In order to secure satisfactory operation of the viscometer in this manner it is of course necessary to calibrate the instrument for the particular oil to be tested and a conversion factor for Saybolt units is necessary.

For proof of the above statements we need only to consider Poiseuille's equation for viscosity, which is:

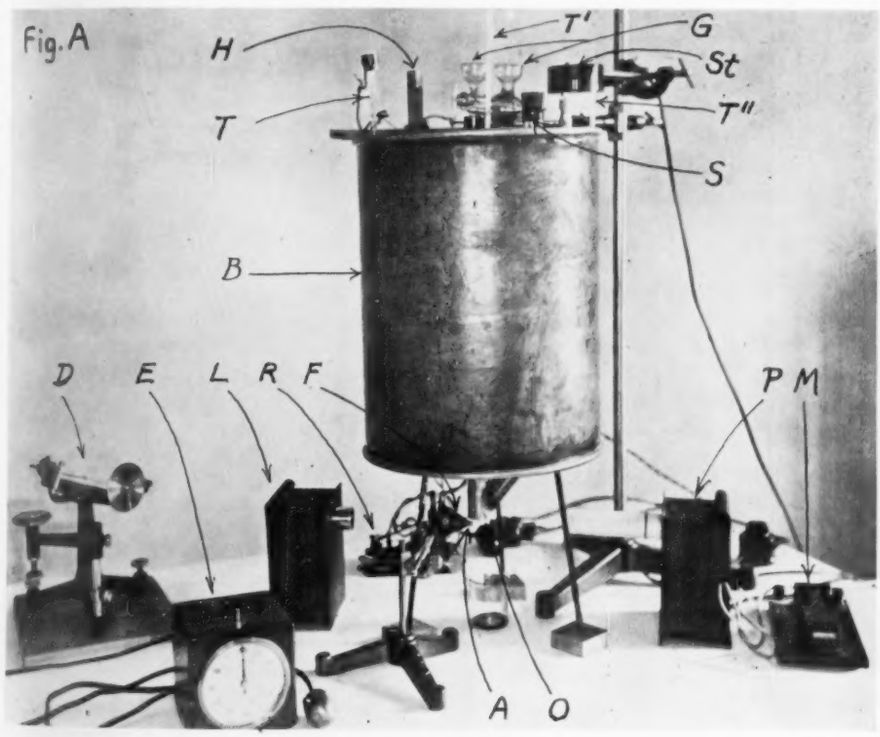
$$H = \frac{\pi h d g R^4 t}{8 l V}$$

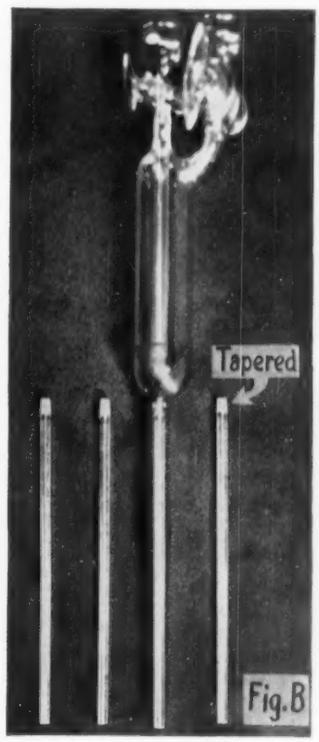
where h represents the effective height of the liquid; d, the density; g, the acceleration of gravity; R, the radius of the capillary tube; l, the length of the capillary and t, the time of flow of V cubic centimeters of oil.
This equation becomes:

$$H = \frac{\pi h d^2 g R^4 t}{8 l m}$$

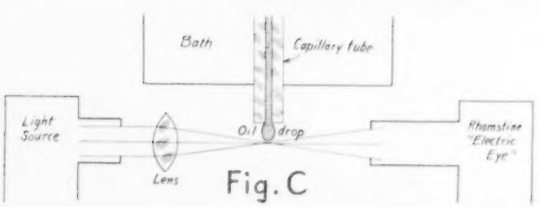
Since $\frac{\pi h g R^4}{8 l} = \text{constant}$, then, $H = \frac{d^2 t C}{m}$, where C is the instrument constant.

Since the surface tension of lubricating oils is practically constant for constant temperature, the weight of a single drop of all lubricating oils must be practically





A—Small aperture of light shield
B—Bath vessel
D—Du Nouy's surface tension apparatus.
E—Electric clock
F—Lens for focusing light
G—Glass viscometer
H—To electric heater
L—Light source
M—Magnetic counter
O—Orifice
P—Photoelectric cell
R—Heating element relay
S—Sample of oil to be tested
St.—Electric stirrer
T—Thermostat
T', T"—Thermometers



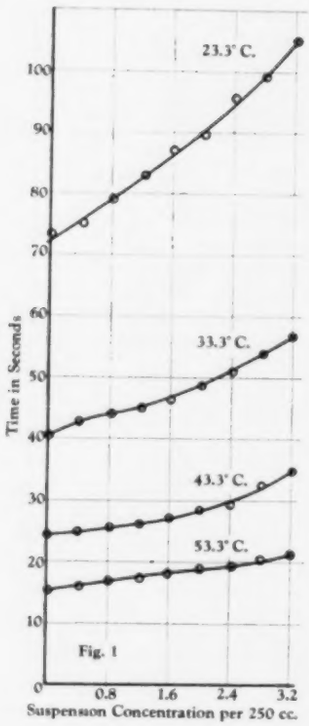


Fig. 1

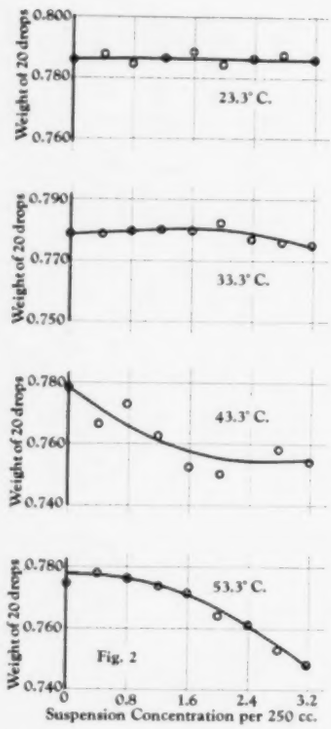


Fig. 2

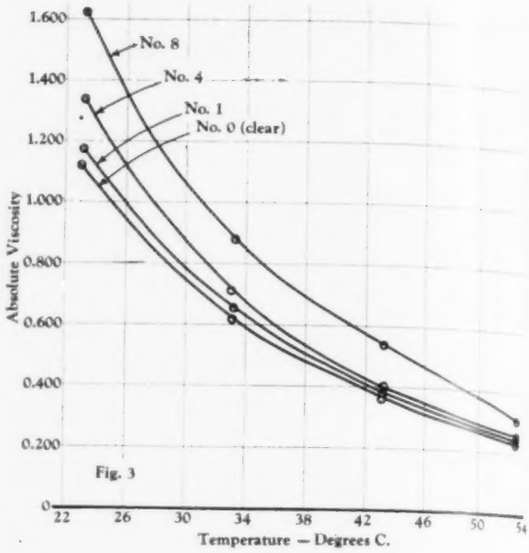


Fig. 3

NOTE—In Figs. 1 to 3 inclusive are shown the results obtained with the "first series" solutions; in Figs. 4 to 9 are shown the "second series" results.

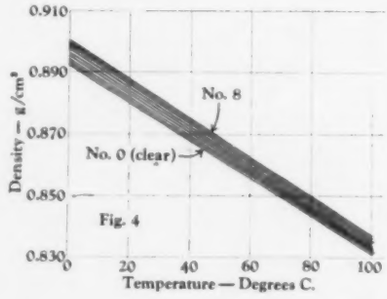


Fig. 4

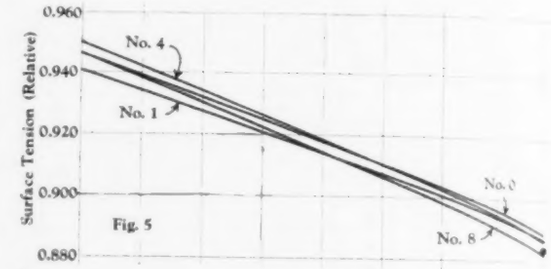


Fig. 5

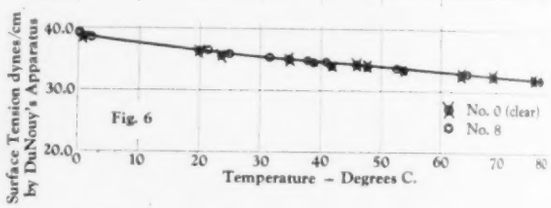


Fig. 6

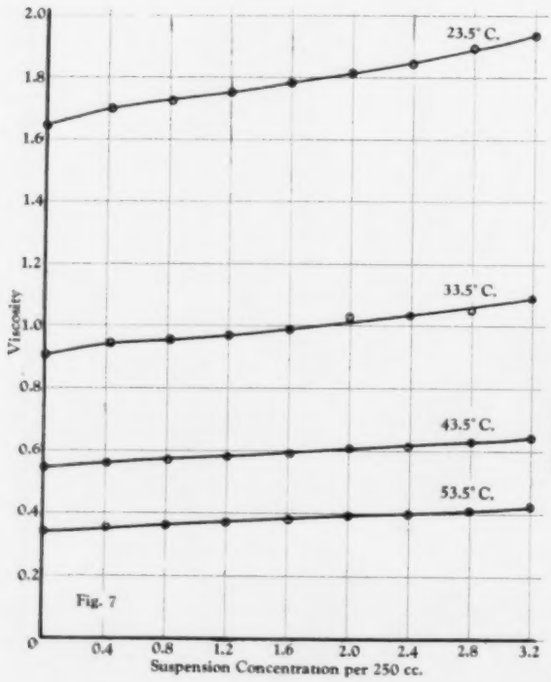


Fig. 7

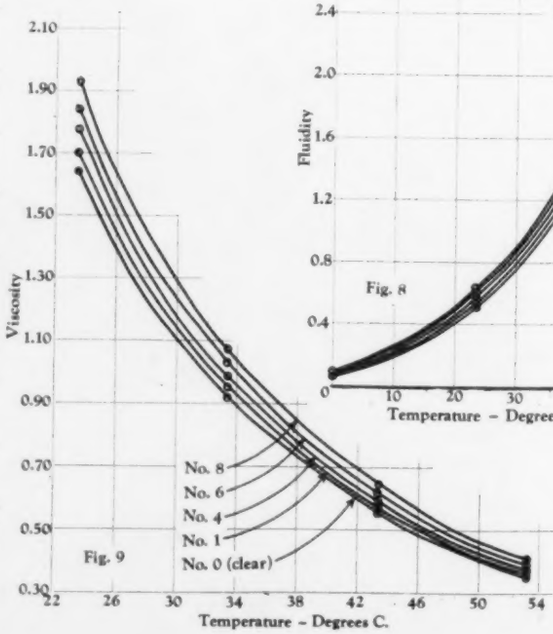


Fig. 9

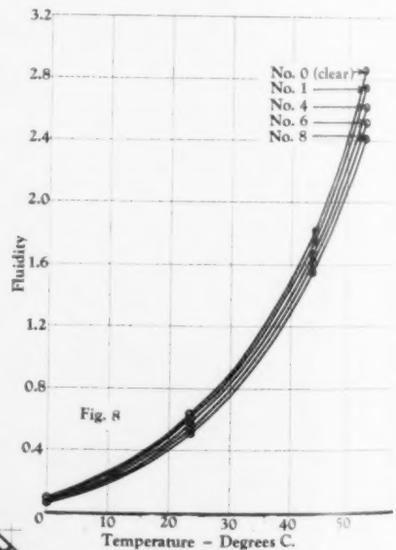


Fig. 8

a constant. If the photoelectric counter is used to record the total number of drops and the time during the flow of this total number of drops is measured, then we have sufficient data for the viscosity determination. The equation now becomes,

$$H = \frac{d^2tk}{N}$$

Suppose the absolute viscosity for a certain oil is determined with this instrument. Then this oil can be used as a standard. So that

$$\frac{H_s}{H} = \frac{\frac{d_s^2 t_s\ k}{N_s}}{\frac{d^2 t\ k}{N}} = \frac{d_s^2 t_s N}{d^2 t\, N_s}$$

If the magnetic counter of the photoelectric circuit is connected to an electric clock in such a manner as to stop the clock (say on the hundredth drop) then $N = N_s$ and we have

$$H = \frac{H_s\ d^2\ t}{d_s^2\ t_s}$$

If $d = d_s$, then

$$H = \frac{H_s\ t}{t_s}$$

A photoelectric counter could be used conveniently in place of a volumetric measure with the Saybolt Universal Viscometer if it were not for the fact that the hydrostatic pressure continually changes during the test. With the above type of instrument this is not the case and we have here also the advantage of an instrument which can be used to measure absolute viscosity and relative viscosity.

TEST RESULTS

There was a decided increase in the viscosity for an increase in concentration of suspension at all temperatures. This increase in viscosity due to the addition of carbon is not due to the change in density to any appreciable extent, but to a colloidal effect. In this case the particles come together to form groups which are held together by some form of physical or chemical attraction, thereby slowing down or preventing flow.

The absolute viscosity drops decidedly with an increase in temperature for each suspension and clear oil for both series. This change in viscosity for change in temperature is shown in Fig. 3 and Fig. 9 for both series respectively. Fig. 8 shows the effect of changes in temperature on the fluidity for concentration No. 1, concentration No. 4, concentration No. 6, concentration No. 8 and clear oil. It was thought that by plotting fluidity a straight line might be obtained but we see that this too is a curved line. Values were taken at 0°C. for these samples and the fluidity determined. The drop in viscosity for an increase in temperature is greater for No. 8 than for suspension No. 6, greater for No. 1 than for clear oil. The curves tend to converge at higher temperatures and to separate more and more as the temperature is decreased. This indicates that at higher temperatures the viscosity of suspensions of carbon and clear oil are more nearly the same than at low temperatures.

It may be noted, also, that the viscosity tends to become constant at higher temperatures. The fact that these curves separate considerably as the temperature falls indicates that the presence of carbon, and perhaps other impurities, suspended in oil would affect the ease with which a motor would start on a cold morning. In extremely cold weather the increase in the viscosity due to these impurities would have a tremendous effect.

Variation of Viscosity with Temperature and Carbon Suspensions. Variation of Relative Surface Tension with Temperature. (Second Series.)

Wt. of Carbon (grams)	Density (g./cm³)	Wt. of 20 Drops (grams)	Viscosity $\left(\frac{\text{dynes sec}}{\text{cm}^2}\right)$	Fluidity $\left(\frac{\text{cm}^2}{\text{dynes sec}}\right)$	Kinematic Viscosity $\left(\frac{\text{poises}}{\text{g./cm}^3}\right)$
			Temperature 23.5°C.		
0.000	0.8780	0.9290	1.6550	0.6045	1.885
0.416	0.8790	0.9277	1.7050	0.5870	1.940
0.814	0.8800	0.9300	1.7300	0.5785	1.966
1.200	0.8805	0.9320	1.7500	0.5715	1.989
1.618	0.8810	0.9325	1.7840	0.5605	2.025
2.007	0.8812	0.9321	1.8180	0.5500	2.064
2.402	0.8825	0.9355	1.8470	0.5419	2.092
2.802	0.8832	0.9345	1.8910	0.5292	2.141
3.210	0.8840	0.9335	1.9350	0.5172	2.190
			Temperature 33.5°C.		
0.000	0.8715	0.9210	0.9160	1.0920	1.051
0.416	0.8727	0.9160	0.9500	1.0540	1.088
0.814	0.8741	0.9180	0.9522	1.0500	1.089
1.200	0.8750	0.9210	0.9730	1.0280	1.112
1.618	0.8760	0.9240	0.9910	1.0090	1.130
2.007	0.8770	0.9200	1.0330	0.9693	1.178
2.402	0.8775	0.9225	1.0340	0.9673	1.179
2.802	0.8784	0.9255	1.0500	0.9530	1.195
3.201	0.8794	0.9180	1.0750	0.9310	1.336
			Temperature 43.5°C.		
0.000	0.8660	0.9135	0.5505	1.8175	0.636
0.416	0.8665	0.9100	0.5615	1.7810	0.648
0.814	0.8680	0.9155	0.5680	1.7610	0.655
1.200	0.8690	0.9110	0.5830	1.7150	0.671
1.618	0.8700	0.9095	0.5925	1.6890	0.682
2.007	0.8705	0.9080	0.6125	1.6320	0.704
2.402	0.8710	0.9120	0.6185	1.6170	0.711
2.802	0.8715	0.9115	0.6300	1.5880	0.723
3.201	0.8725	0.9100	0.6425	1.5570	0.733
			Temperature 53.5°C.		
0.000	0.8600	0.9096	0.3490	2.8650	0.406
0.416	0.8610	0.9095	0.3661	2.7610	0.425
0.814	0.8610	0.9062	0.3650	2.7400	0.424
1.200	0.8620	0.9070	0.3700	2.7040	0.429
1.618	0.8640	0.9080	0.3794	2.6370	0.439
2.007	0.8630	0.9050	0.3899	2.5650	0.452
2.402	0.8650	0.9092	0.3942	2.5350	0.456
2.802	0.8660	0.9040	0.4050	2.4700	0.468
3.201	0.8660	0.9020	0.4122	2.4270	0.476

The field of force which exists at a free face of a solid or liquid is due to the unbalanced attractions of the molecules, and the tangential component of this field constitutes the surface tension. The curves in Fig. 2 indicate the effect of suspended lamp-black on the surface-tension, while the curves in Figs. 5 and 6 definitely indicate that the suspended particles of carbon have no effect on the surface tension. Since the instruments with which these determinations were made were different for the two series it is probable that the deviation from a straight line at higher temperatures as represented in Fig. 2 is due to experimental error. On the other hand the kinds of lamp-black used in the two series were quite different, and this may account for the difference. It would seem safe to say that the surface tension does not change when carbon is suspended in oil. This is indicated in Figs. 5 and 6. The drop in surface tension with increase in temperature is the same for all samples.

These samples are to be tested further for adhesion. Concentration No. 8 and clear oil have been tested for "oiliness" with the Herschel Oiliness Machine, but no difference in readings can be detected for these samples with this instrument.

ACKNOWLEDGMENTS

Thanks are due Professor C. M. Heck, North Carolina State College of Agriculture and Engineering, and Professor S. R. Williams of Amherst College for many helpful suggestions. The writer also wishes to thank Dr. W. H. Herschel for the use of his machine and the American Instrument Co. for getting it in operation.

Furnace Temperature and Heating-rate Control by Dilating Wire

By C. T. EDDY*, F. W. VIGELIUS†, and E. C. DAVIS†

PRECISION work in metallurgy dealing with thermal analysis, dilatometry, etc., requires the accurate control of rate of heating, while problems dealing with isothermal reactions, recovery, and the like require accurate control of temperature. The latter control (constant temperature) is obtainable in many forms of commercial units, few of which, however, exactly suit the requirements imposed by the conditions obtaining in research in these fields.

The dilating wire is a desirable means of controlling the temperature or the rate of heating of small electric resistance furnaces suitable for this work.[1] Its first satisfactory application to this purpose is reported by Chévenard.[2] He used the principle in controlling the temperature of his dilatometer furnace. He also devised two systems whereby the constant temperature control device could be used for the purpose of controlling the rate of heating of the furnace. However, this was done by empirical means, and the device thus modified could be used only on one furnace or on furnaces of exactly the same characteristics.

Unlike most control systems, which operate upon evidence of temperature error by making crude adjustments to the line current, the dilating wire causes the line current to vary gradually and so to follow a predetermined plan. All tendency for the furnace temperature to "hunt" is removed because the heat is controlled at the furnace windings, where and when it is liberated. Temperatures in the muffle—and for that matter, the temperatures of the gradient through the insulating material of the furnace—are all directly established as a result of furnace characteristics. In addition, the dilating wire compensates for power line variations by holding the current to proper values regardless of any fluctuation of line voltage.

When the evaluation of magnitudes of transitions is desired the successful operation of a thermo-analyzer depends largely upon the ability to vary the furnace temperature at a constant, slow rate. As a result, much experimental work was done on the dilating control wire, and many runs were made on various furnaces, with a view to causing the muffle temperatures to vary at a constant rate.

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†Research Engineer, Michigan College of Mining and Technology, Houghton, Michigan.

[1]The development of the apparatus described in this paper was the outgrowth of the development of an automatic apparatus assembly for thermal analysis under a National Research Council grant in 1934. The assembly in its original form was described in *Review of Scientific Instruments*, Vol. 4, 1933, pages 200-205.

[2]Fours de Laboratoire et Régulateurs de Température. *Revue de Métallurgie*, Vol. 28, 1931, pages 453-468.

FURNACE

It was found experimentally that the temperature of small laboratory furnaces could be made to rise at practically constant slow rates by starting the runs with definite amounts of current, and increasing this current by definite amounts in equal periods of time. Figs. 1 and 2 show the results of tests on two entirely different furnaces, while Fig. 3 presents this information in a different way and shows the necessary rate of current increase as well as the necessary starting current for various rates of temperature rise. Fig. 4 shows the effect of varying the starting current while keeping constant

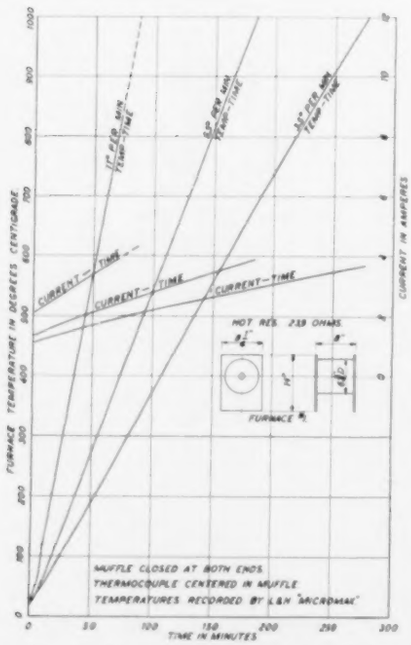

Fig. 1. Linear Temperature-time Runs Showing Required Current Input

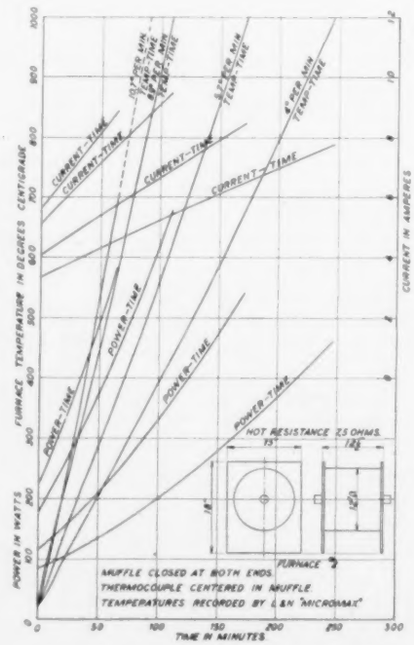

Fig. 2. Linear Temperature-time Runs Showing Required Current and Power Inputs

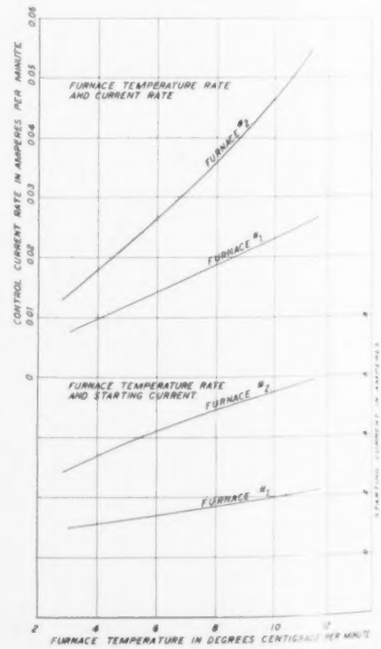
CONTROL CURRENT RATE IN AMPERES PER MINUTE
FURNACE TEMPERATURE RATE AND CURRENT RATE
FURNACE #2
FURNACE #1
FURNACE TEMPERATURE RATE AND STARTING CURRENT
FURNACE #2
FURNACE #1
FURNACE TEMPERATURE IN DEGREES CENTIGRADE PER MINUTE

Fig. 3. Necessary Current Conditions for Linear Furnace Temperature Runs

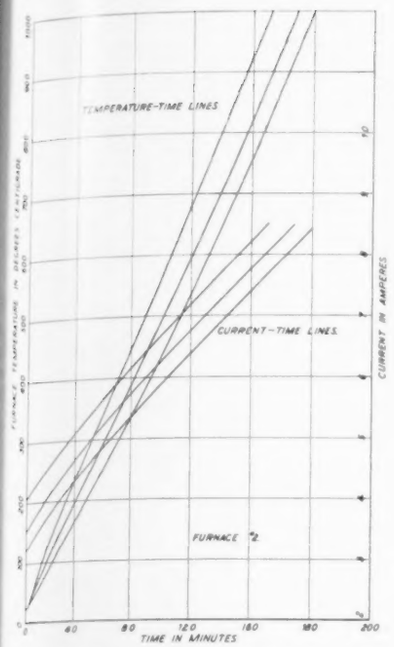

Fig. 4. Influence of Starting Current on Linear Temperature-time Runs

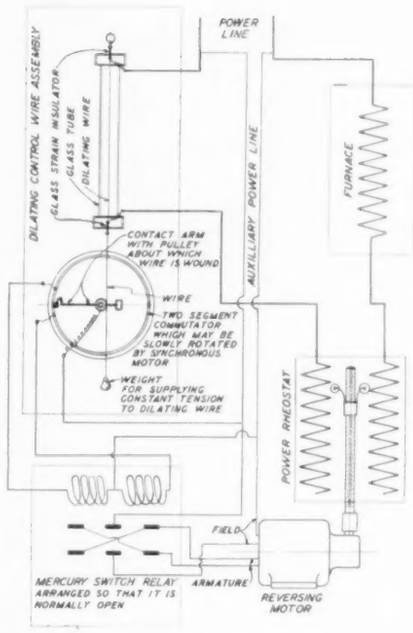

Fig. 5. Diagrammatic Sketch of Apparatus

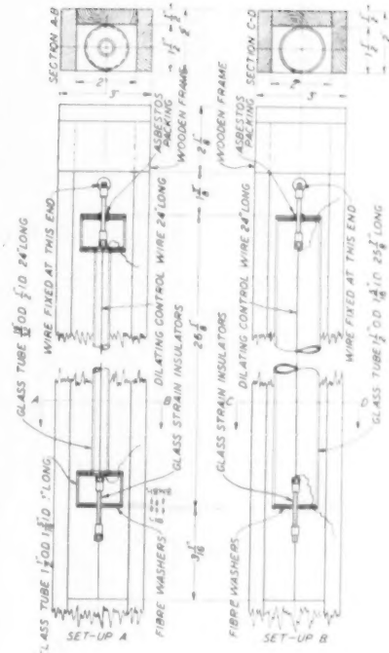

Fig. 6. Sketches of Set-ups

the rate of current increase. At high furnace temperatures the current rate is the major control factor while at the lower temperatures the starting current exerts the greater influence.

It is difficult to calculate furnace behavior throughout straightline temperature runs because a condition of thermal equilibrium never exists. However, an attempt is being made to establish some readily obtainable furnace index from which the two current conditions may be easily predicted.

CONTROL UNITS

In order to duplicate any furnace run, such as those shown on Figs. 1 and 2, it is only necessary to duplicate the current input to the furnace. This may be done by allowing the proper starting current to flow and then increasing this current at a constant rate. The apparatus necessary to accomplish this consists of two principal units—the dilating control wire assembly, and a power rheostat which is automatically operated by a motor drive commanded by the control unit. The dilating wire, the rheostat, and the furnace are all connected in series across the power line. A diagrammatic sketch is shown in Fig. 5. Convenient switching and protective equipment may also be included in a separate unit.

In principle the control wire is fixed at one end and loaded at the other end so as to maintain a constant tension. The furnace line current passes through this wire, and its heating effect causes a dilation in accordance with temperature changes. The control wire is enclosed in a glass tube in order that most of the heat loss should be by radiation rather than conduction, convection, etc. The glass tube is mounted in a wooden frame. The size, shape, and mounting of this tube influence the operation, and these factors will be referred to as the "set-up" throughout this paper.

All motion of the lower end of the wire—elongation or shortening due to a change of temperature—causes angular displacement of a contact arm which turns within a two-segment commutator. This commutator is mounted co-axially with the contact arm and, by means of a synchronous motor, it may be rotated independently of the contact arm at any desired rate. When contact is established with one segment, a relay circuit closes a mercury switch so as to operate the rheostat motor in one direction, while contact on the other segment serves to reverse the operation of the rheostat motor. This in turn increases or reduces the rheostat resistance, and so lowers or raises the line current. Connections are such that an elongation of the wire causes resistance to be added to the circuit, with a consequent lowering of the line current, and cooling and shortening of the wire result. Conversely, a shortening of the wire as evidenced by too small a line current causes the rheostat to remove resistance from the circuit and so increase the current. The contact arm automatically hovers at the neutral or "open" point between the two commutator segments, and any change in the control wire length is opposed and corrected.

If, now, the commutator itself is rotated, the control unit will function to require a change in temperature of the control wire corresponding to the necessary change in length of the wire. As a consequence more or less current, as the case may be, must flow through the control wire and series circuit.

CONTROL WIRE ASSEMBLY

Since the action of the control depends upon the change in temperature of the control wire and consequent dilation, the performance of the control is influenced by the heat-emitting properties of the wire as well as by the heat-dissipating properties of the set-up.

Two resistance alloys made by the Driver-Harris Co. were investigated in order to determine their fitness for control wire use. These materials were "Advance" and "Nichrome V," and their dilating characteristics were established by determining their coefficients of linear expansion with a Leitz dilatometer.

For various practical reasons it was decided to establish 24" as the length of the control wire. Also, most of this work has been done using a No. 24 B and S gage wire. Fig. 6 shows two different set-ups having different heat-dissipating characteristics.

Fig. 7 shows a complete calibration of a 24″ length of No. 24 "Advance" used as a control wire and mounted according to set-up "A." Temperature, power loss, and current are all plotted against dilation in inches per 24″ as the abscissa. However, this dilation can be more conveniently considered in terms of the minutes of time required for a constant-feed device to feed an equivalent distance, and accordingly this scale is added. Calibration was done with direct current from a storage battery in order to have constant voltage. The line marked "Dilation due to Temp. Rise" is plotted directly from the dilatometer measurements.

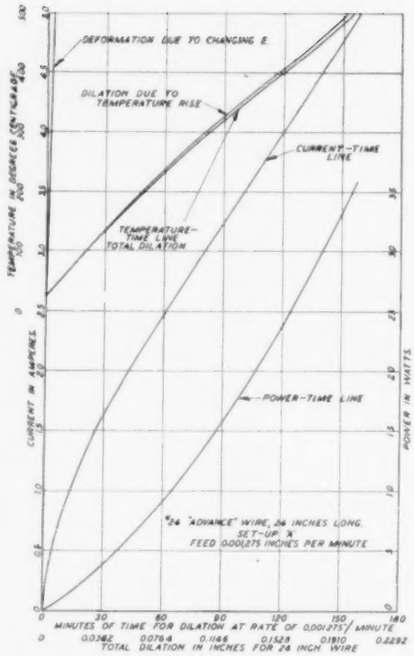
DEFORMATION DUE TO CHANGING E
DILATION DUE TO TEMPERATURE RISE
CURRENT-TIME LINE
TEMPERATURE-TIME LINE TOTAL DILATION
POWER-TIME LINE
#24 "ADVANCE" WIRE, 24 INCHES LONG SET-UP "A" FEED 0.001275 INCHES PER MINUTE
TEMPERATURE IN DEGREES CENTIGRADE
CURRENT IN AMPERES
POWER IN WATTS
MINUTES OF TIME FOR DILATION AT RATE OF 0.001275" / MINUTE
TOTAL DILATION IN INCHES FOR 24 INCH WIRE
0.0382 0.0764 0.1146 0.1528 0.1910 0.2292

Fig. 7. Calibration of control wire.

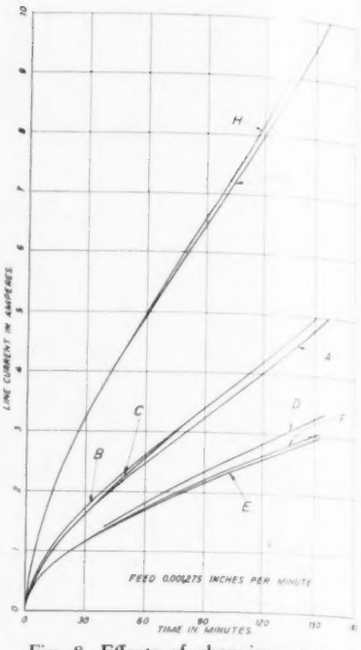

Fig. 8. Effects of changing set-up, and of shunting, upon current-time lines.

Although few data are available on the effect of temperature changes between room temperature and 470° C. on the modulus of elasticity of "Advance" and "Nichrome V," it seems logical to expect the modulus to lower with increase of temperature. The effect would be to increase the deformation of the wire which is arbitrarily held under a constant tension of 4 lbs. (12,600 lb./in.^{2} for No. 24 gage). Thus definite elongations require lower compensating temperatures, so that less power and current are actually needed.

A crude measure was made of the modulus of elasticity, E, using the control apparatus so modified that the length of the wire could be measured under different loadings and at different temperatures. Results:

Material	*E at Room Temperature*	*E at 470° C.*	*% Reduction E*
Advance	18,200,000	15,550,000	14.5
Nichrome V	18,200,000	15,000,000	17.6

In the case of "Advance" wire at room temperature there is a total elongation of 0.016,60″ in the 24″ length, due to the loading. When the temperature is raised to 470° C., this elongation becomes 0.019,45″, an increase in total elongation of 0.002,85″ due to the lowering of E. This deformation is assumed to have a linear relation with temperature and is so plotted with the title "Deformation due to Changing E."

The combination of the elongations due to both dilation and changing E results in a total elongation as shown by the temperature-time line. The location and shape of this line are entirely dependent upon the material from which the control wire is made.

The power-time line, obtained by measuring watts dissipated by the control wire throughout a run, shows the loss necessary to maintain the various temperatures. Since the mass of the control wire is small, the heat required to raise it to a given temperature is considered equal to that required to hold it at that temperature. Consequently, the shape of this line depends upon factors which control the heat-dissipating properties of the set-up; the faster that heat is dissipated the more power is required to maintain a temperature. Specifically, the size and mounting of the protective tube and the gage of the control wire are important factors.

The current-time line follows directly from the power-time line, and is plotted from current measurements made throughout runs. Since $I = \sqrt{(W/R)}$ the shape of this line depends upon the power-time line and upon the electrical resistance of the control wire, and reflects the effect of the temperature coefficient of resistance for the material in use. Since the control wire is connected in series with a furnace under operating conditions the current is common to both units and serves as the controlling link. It will be observed that the current-time line is substantially straight over a large part of its length under the set-up conditions shown, and this fact allows for a varying of current at a fairly constant rate. This is one of the conditions necessary to cause a furnace temperature to rise at constant rate as mentioned above. It is only necessary that the rate of current increase and the starting current be correct and compatible, in order that the desired furnace temperature rise may take place. The first condition is met by the mechanical feed of the control unit; the second condition by adjusting the rheostat at the start of the run.

FACTORS WHICH MODIFY THE CALIBRATION LINES

Any change in the physical set-up of the control wire assembly, which alters evolution or dissipation of heat, modifies the slope of the current-time line. Evolution of heat depends upon the resistance of the control wire and the current it is carrying; dissipation upon the physical set-up. A change in the rate of constant uniform feed affects the resulting current rate in direct proportion. The useful range through which the current is caused to vary is limited at the bottom by the rapid bending of the current-time line to zero, and at the top by the maximum allowable working temperature of the wire. To control larger currents, the wire may be shunted, provided that the proportionality between its resistance and that of the shunt be maintained at all temperatures: by using a shunt which duplicates the wire, mounted in a duplicate set-up. Fig. 8 illustrates these considerations and a key describing the various lines is tabulated below:

A—No. 24	"Advance"	Set-up "A"	
B—No. 24	"Advance"	Set-up "A"	Cooled by air from fan
C—No. 24	"Advance"	Set-up "B"	
D—No. 26	"Advance"	Set-up "A"	
E—No. 24	"Nichrome V"	Set-up "A"	
F—No. 24	"Nichrome V"	Set-up "A"	Without packing at top of tube
G—No. 24	"Advance"	Set-up "A"	With duplicate shunt (Compare with line A)
H—No. 24	"Advance"	Set-up "A"	With similar shunt wire but not in similar set-up

Although room temperature changes modify the cooling of both the control wire unit and the furnace itself, tests indicate no great differences in performance under such varying conditions.

"True-direction" Aircraft Instruments

For previous articles and discussions see *Instruments*, Feb. 1935, pages 30-31; April 1935, page 102; May 1935, page 119. Our forum remains open: send in your reports . . . MFB

To the Editor:

The two experiments which Dr. Gunn cites (May *Instruments*, page 119) as defense of his belief that the earth's magnetic field cannot be used as a fixed reference system are interesting but I question their use as proof of his point. Consider the beam of slow moving electrons parallel to the axis of the plane. Obviously it was necessary to house the electron beam in some sort of a container which could be evacuated. In addition this container was undoubtedly mounted inside of the plane's fuselage. As soon as the plane started to move the container and the fuselage started cutting the vertical component V of the earth's magnetic field, causing a potential to be set up from one side of the fuselage to the other or from the same side of the container to the other. Such a potential would set up an electrostatic field across the beam which would exert a force on the electrons equal and opposite to the force exerted by the intersection of the electrons with V.

In the case of the vacuum-tube instrument the actions in the tube can be described progressively as follows: When the tube is stationary and only the "A" battery circuit closed, electrons are emitted from the cathode until the cathode acquires a sufficient positive charge to attract back to itself all electrons emitted. When both the "A" and "B" battery circuits are closed the positive charge on the plate sets up a stray electrostatic field through the grid to the cathode which opposes the positive charge of the cathode and attracts some electrons to the plate. This flow of current through the grid can be thought of in terms of the external circuit of a generator; that is, a potential gradient is set up which causes electrons to flow from the negative to the positive. After the electrons have passed through the grid they are attracted to the anode and returned to the cathode through the "B" battery to set up a continuous current. This current can be stopped by nullifying the effect of the stray field through the grid and in addition overcoming the effect of the initial velocities of the electrons emitted from the cathode. In the conventional 3-element vacuum tube this is accomplished by impressing on the grid a potential which sets up an electrostatic field between the grid and the cathode opposite in direction and approximately equal to the stray field. In the vacuum-tube generator the stray field is nullified by the generation of a counter electromotive force through the space it occupies. This action is similar to the action of the counter electromotive force in a d.-c. motor.

Assume a d.-c. motor having a potential impressed across its terminals and a stationary armature. Electrons flow through the armature winding from the negative terminal to the positive terminal. Now if the armature is allowed to rotate it accelerates in speed and at the same time the current flowing decreases due to the counter electromotive force generated in the armature winding. The polarity of the counter electromotive force with respect to the circuit is the same as the polarity of the impressed electromotive force. In the case of the vacuum-tube generator, as the tube is accelerated through V so that an induced potential is set up across the grid having the same polarity as the stray field, the effect of the stray field is increasingly nullified, causing more electrons to be returned to the cathode and thereby decreasing the plate current until zero current flows in the plate circuit. If conditions are such that the polarity of the potential induced by movement through V is opposite to the polarity of the stray field, then the plate current is increased—the same as the current through a d.-c. motor would increase if the motor were made to rotate backwards.

Although the plate circuit of the vacuum-tube generator is a closed loop, part of which comprises the interior of the tube and part of which comprises the external plate circuit, and although movement of the tube through V causes V to be cut by both of these parts of the closed loop, the effect on the portion of the circuit passing through the magnetic grid is considerably greater than the effect of V on the external plate circuit, because in the first case the effect acts upon the stray electrostatic field through the grid as set up by the positive potential on the anode whereas in the second case the action affects the anode potential. Since the tube is so designed that the strength of the stray field is smaller than the strength of the electrostatic field in the vicinity of the anode, the same amplification effect is present as obtains in the conventional 3-electrode tube and the effects around the closed circuit are not zero. The plates serve as an electrostatic shield for external electrostatic fields. Rotation of the tube in an external electrostatic field might set up an alternating current in the external plate circuit, but this can be nullified by enclosing the whole tube in an electrostatic shield. Potentials generated in such a shield by cutting of V should not affect the stray field through the grid due to the shielding effect of the plates.

Referring to Dr. Gunn's experiment with the cylinders, it appears that such a device would be one form of homopolar generator. If I understand his set-up, an electric circuit consisting of a connection between the two concentric cylinders, the brushes and external connections, was placed in a magnetic field set up by the solenoid. When the cylinders were rotated with the solenoid stationary a potential was set up in the connection between them. No potential was generated in the external connections because the external connections were not moving with respect to the solenoid. Now, when the cylinders were stationary and the solenoid was rotating, assuming that the magnetic field rotated with the solenoid, both the external connections and the connection between the cylinders were cut by the magnetic field and potentials were generated in the loop which added to zero. Assuming the cylinders to be rotated in the same direction and at the same speed as the solenoid and assuming the magnetic field to be rotating with the solenoid, then zero potential would be generated in the connection between the cylinders but the potential generated in the external circuit should give the same effect on the electrometer. When the cylinders are rotated at any speed the potential generated in the cylinders is different from that generated in the external connections irrespective of rotation of the solenoid, and an effect is detected in the loop. When the solenoid is rotating its effect on the cylinders is equal and opposite to the effect on the external circuit and no resultant effect in the loop can be detected. Nothing different can be expected from a combination of these conditions. It would therefore appear that the action can be explained even though rotation of the field with the solenoid is assumed.

N.Y. & Queens Elec. L. & P. Co., J. A. Brooks
New York, May 29, 1935 *Assistant Electrical Engineer*

To the Editor:

The difficulties encountered in the design of a true direction finder do not rest on an absolute principle which makes it impossible to obtain orientation from readings confined to observations within a moving object. Different kinds of fields offer different possibilities in this respect. Take, for instance, a *uniform, stationary* field. A slight consideration will show that there are no theoretical obstacles against measurements of the speed with which the object *crosses* the lines of the field, irrespective of how this is being done. On the other hand, it will never be possible to obtain any information about any movements parallel to the lines of the field. Velocity components square to the field are thus always obtainable but not the parallel ones. If we had, on the other hand, an *oscillating*, uniform field, the Doppler principle could be brought into play in order to obtain the parallel component. On our earth only the stationary magnetic field is available and before any instruments for complete orientation, utilizing above principles, could be put on the market, it would be necessary to create such an oscillating field beside the present magnetic field. This is, of course, a technical possibility but, perhaps, not an economic one.

Even the *gravitational* field of the earth can be utilized, however, by an integration-accelerometer as already suggested by Mr. Steensen. The instrument acts in this case as an "ether-log" making possible the finding of position and direction by dead reckoning.

A curious example of an "apparatus" for the autarchial determination of the relative movement of the earth in reference to the moon is provided by the tides. The motive power in this case is provided by a locally varying potential difference of the gravitational field.

Star Electric Motor Co., Lawr E. Widmark,
Bloomfield, N. J., May 12, 1935 *Chief Engineer*

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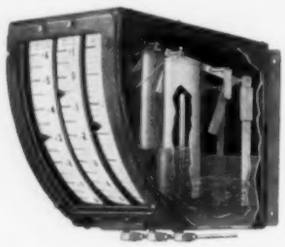

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By PERRY A. BORDEN† and M. F. BEHAR**

4. Lagged Demand Meters
(*Continued*)

(c) Magnetically Lagged Type

The only magnetically lagged demand meter which has reached the stage of commercial production is the General Electric "Type W" demand indicator, first appearing about 1910. This instrument, Fig. 43-33, is essentially an induction type polyphase indicating wattmeter having an abnormally strong magnetic damping system. As in the polyphase watthour meter, two disks on a common spindle constitute the moving element; but in this instrument the two electromagnetic elements of the polyphase metering system act on the upper disk, leaving the lower free to rotate in the combined fields of a group of powerful permanent magnets. The rotating element is controlled and restrained by a system of spiral springs which permits it to make three complete revolutions, in which the pointer—driven by a dog connected to the spindle through a 3/1 gearing—traverses the dial but once. The pointer is held at its maximum deflection by a small ratchet, manually released when the meter reading is taken. The characteristic of this meter is essentially logarithmic, the element following the same law on increasing and decreasing loads; but mechanical limitations restrict it to a relatively short time interval.

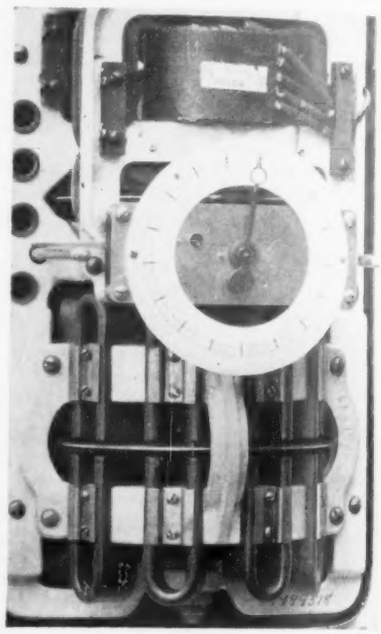

Fig. 43-33

(d) Capillary Flow Lagged Type

Essentially, the principle employed in fluid-flow type demand meters is extremely simple—a homely analogy being the common hour-glass: the level of the liquid in the bottom receptacle is the "pointer"; the quantity of liquid accumulated in the bottom receptacle depends both on the time during which flow took place and on the rate of flow. The rate of flow through a capillary depends on the head which causes flow; and in a demand meter this head is made to be a function of the load—approximately a sine function in the reservoir-tilting designs. With an upper reservoir of infinitely large diameter this head (and the rate of advance of the "pointer") would remain constant while the load remained steady; with a purposely small upper reservoir the flow rate at constant load diminishes according to a rough approximation of the logarithmic decrement function—the exact law depending, of course, on the geometric design of the "hour-glass" and on the relation of the sine of the angle of tilt to the value of the load at any moment.

*Fifteenth chapter (XLIII) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Béhar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. Each chapter is subjected to a final revision shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright. To be issued in book form on or about Jan. 1, 1936.

†Member A.I.E.E. **Editor, *Instruments*

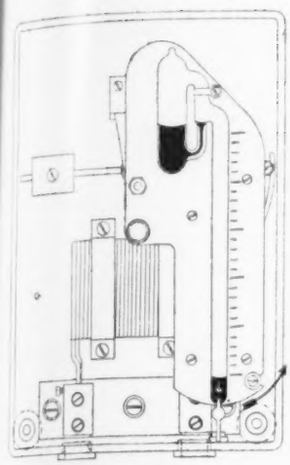

Fig. 43-34

For a commercial example of this type we may select the demand meter made in England by the Reason Mfg. Co. In this meter (Fig. 43-34) a solenoid type electromagnetic element tilts a two-reservoir system in proportion to the line current, in exactly the same manner as the pointer of an ammeter is deflected, causing some liquid to flow from the upper to the lower reservoir through the capillary. At the beginning of a demand interval the liquid is all in the upper reservoir, so that upon application of any steady load, the *initial* flow rate will be the maximum for this value of load, thereafter diminishing. The demand interval is fixed by the dimensions of the upper reservoir and capillary, and by the viscosity of the particular liquid sealed in at the factory. (It goes without saying that the liquid must be one which has a low temperature coefficient of viscosity within the "room temperature" range.) In addition to the capillary, there is a large-diameter connection between the upper and lower reservoirs: it is for quickly setting at zero by swinging the tube system counter-clockwise $>90°$.

(e) Mechanically Lagged Logarithmic Type

A recent development in mechanically lagged demand meters is the Westinghouse "Type RL," now available as an attachment to watthour meters in place of the regular register. In the registration of demand this device follows a logarithmic law whether the load be increasing or decreasing. Fig. 43-35 is a photograph, and Fig. 43-36 a diagram, of this register.

A and *B* are small crown gears which with planetary gear *G* form a differential which, through the relative speeds of its parts, controls the angular position of involute cam *C*. The cam is mounted on a shaft which connects with demand pointer *D*. An aluminum ball rests against the edge of cam *C* and is positioned between driving disk *E* and driven drum *F*. At the zero position of the cam, the demand pointer is at zero on the scale and the ball is held at the exact center of driving disk *E*. Gear *A* of the differential is driven by the watthour meter; gear *B* by drum *F* of ball mechanism.

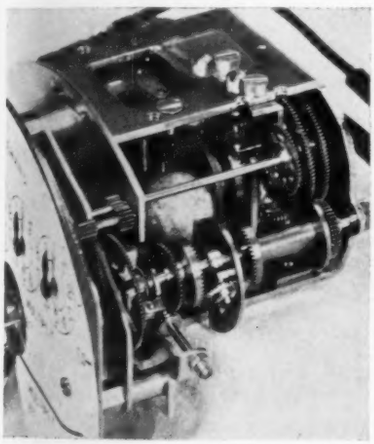

Fig. 43-35

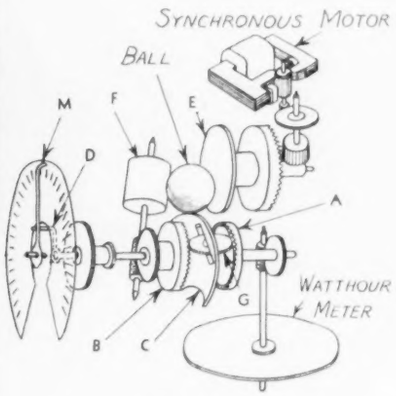

Fig. 43-36

As long as there is no load on the watthour meter, and if the ball is at the zero position, the differential remains at rest and driving disk *E* simply rotates at a constant speed due to a connection with the synchronous timing motor, but no motion is imparted to the ball and the demand pointer remains on zero.

If a load is applied to the watthour meter, its side of the differential is driven at a speed proportional to this load, the cam begins to move and—since drum *F* is tilted at a slight angle—the ball follows the cam and moves a little away from the center of disk *E*. Immediately the ball begins to rotate about an axis which is parallel to the drum and which passes through the contact point between the ball and cam so that there is no friction at this point to prevent free rotation.

Since the ball is resting on drum *F* and rotating about a parallel axis, the drum is driven at the same surface speed as the ball and in turn drives gear *B* in a direction arranged to be opposite to that of gear *A*. Thus the motion of planetary gear *G* with cam *C* is equal to the difference between *A* and *B*; therefore, if for any position the speed of *B* is equal to that of *A*, the cam remains stationary in that position.

Referring again to the position of the ball against driving disk *E*, it is evident that the rotational speed of the ball and, consequently of drum *F*, is proportional to the

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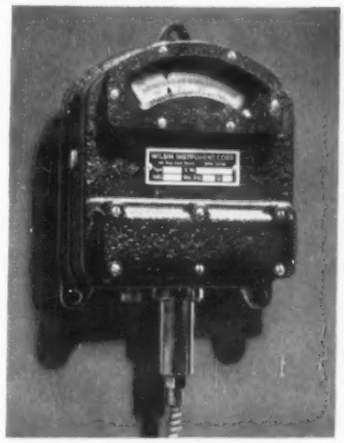

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angular position of the cam since the radius or "rise" of the involute cam is exactly proportional to its angular position. Then for any given load and corresponding speed of *A*, there is a definite position of cam which will give an equal and opposite speed of *B*. The cam moves until this balance point is reached and there remains until the load on the watthour meter changes to a new value.

Since the *rate* at which the cam with the demand pointer *D* moves is equal to the difference in speed between *A* and *B*, it is evident that this rate starts off at a relatively high value, then becomes less and less as *A* minus *B* approaches zero and the final position is approached. For the same change in load, the descending rate as the demand pointer returns to zero varies in exactly the same way. Thus, if the watthour meter stops, gear *B* simply continues to rotate and carries the cam in the reverse direction at a slower and slower speed until finally the ball is again at the center of disk *E* and all motion stops.

All of the above is analogous to a thermal meter, the pointer of which advances at a constantly decreasing speed until the escape of heat just balances the heat input due to the watts in the circuit being measured. In both cases if any load is applied, the time t to reach any point a on the scale is given by the equation $t = \mathcal{T} \log_e \frac{b}{b-a}$ where b is the final reading and a is some percentage of that reading and $\mathcal{T}$ is the time which would be required to reach the former balance point in the thermal meter if there were no escape of heat. Then, if the 90% point is selected, the equation becomes $t = \mathcal{T} \log_e \frac{100}{100-90}$ or $t = 2.302\ \mathcal{T}$.

The designer of this meter has further pointed out[1] that the time element of a given design of thermal meter may only be determined and adjusted by experiment (after first building a model and operating it with various adjustments until the desired value of t is found from which the value of $\mathcal{T}$ may be calculated), whereas in his new mechanical logarithmic meter "we may simulate the desired condition by simply stopping the synchronous motor. Then the watthour meter will carry forward the cam with its attendant demand pointer at a constant speed and will reach a given point in a time which is determined by the gear ratio between the watthour meter and the demand pointer, and which is the value of $\mathcal{T}$ in the above equation."

(f) Mechanically Lagged Straight-line Type

The only commercial example of a mechanically lagged demand meter having a straight line law is the Westinghouse "Type R-O," in which on a suddenly applied steady load the pointer approaches at a uniform rate (*A*, Fig. 43-24) a reading representative of the value of the load. Its operation will be understood by reference to Fig. 43-37. It comprises a watthour meter and wattmeter element both associated with a common electromagnetic system. The watthour meter element has the usual retarding magnets and is geared to an integrating register in the conventional manner. The wattmeter element consists of auxiliary disks moving freely in the air gaps of the electromagnets without interfering with the main disks. The shaft of the auxiliary disks carries a spiral spring, so that its deflection is limited and tends to correspond to that of an

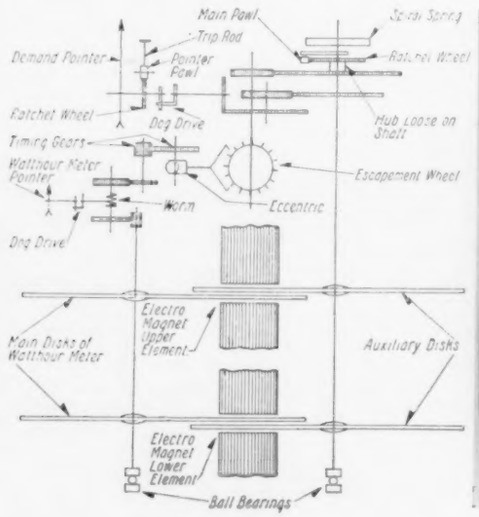

Fig. 43-37

Fig. 43-38

[1] B. H. Smith. A New Type of Demand Meter. *Instruments*, Vol. 7, February 1934, page 41.

indicating instrument. A short pointer or dog represents the position of the auxiliary disks at all times, and also serves to move a pointer which is held in its position of maximum excursion by a releasable pawl, providing on a circular scale an indication of the greatest deflection of the auxiliary element. The rate of deflection of the auxiliary element is controlled by an escapement connected to the auxiliary train through a ratchet, so that the disks may drop back freely upon decrease of the load. The pallets of the escapement are definitely oscillated by the watthour meter element, so that on increasing deflection the auxiliary disks and the indicating pointer tend to approach a position representive of the value of the load and at a speed proportional to the load. Since the ultimate deflection of the auxiliary system and its rate of deflection are both proportional to the load, the time required to reach equilibrium on any load is constant, and is governed by the gear ratios embodied in the train.

5. Volt-Ampere Demand

(a) Indicating or Registering Devices

It has been pointed out that the limiting factor of most electrical apparatus —heating—often is more closely related to the volt-amperes represented in the load than to any other measurable magnitude; and for this reason the measurement of volt-amperes is probably of more use as a basis of demand determination than as the basis of integration or of a simple graphic record. Any of the standard types of block-interval demand registers fitted to or built into a volt-ampere-hour meter will provide an integrated volt-ampere demand. A meter or register of the lagged demand type will read demand in volt-amperes if its measuring system be actuated by any one of the methods which have been described for volt-ampere measurement.

Combination Volt-ampere-demand and Watthour Meter (Lincoln "4L-2")

A combination instrument developed especially for metering loads in which the billing is based on a contract which takes cognizance of both energy consumption and volt-ampere demand is manufactured by the Sangamo Co. in Canada. This Lincoln "4L-2" meter, Fig. 43-38, embodies two single-phase watthour meter elements connected through a differential register to measure polyphase power (see *Instruments*, April 1935, page 90) and also a Lincoln thermal storage meter which may be set to indicate demand on a volt-ampere basis. By ingenious design the transformers which are essential to the thermal wattmeter circuit (see Fig. 43-31) are also made to perform the function of phase-shifting transformers, and a tap-switch operable from the outside of the case of the instrument enables the user to select the best value of power factor for volt-ampere determination. It will be remembered (see *Instruments*, April 1935, page 95) that by proper selection of phase-shift it is possible to measure volt-amperes with a negligible error, through a considerable range of power factor variation. A curve appearing on the nameplate of the instrument enables the user to determine from the relative speeds of the meter elements the value of power factor at which the tap-switch should be set, so that the one instrument may be adjusted to perform volt-ampere demand measurement on any type of load within its scope, without the need for auxiliary equipment either in testing or operation.

(b) Recording Volt-Ampere Demand Meters.

As has already been pointed out, the recording demand meter differs from the simple recording instrument in that the element of *time* is definitely incorporated in the measurement performed (as well as in chart travel) so that the demand value is directly determined by the excursion of the pen or stylus across the graduations of the chart. When the recording principle is applied to demand meters of the block-interval type, as in some of the forms already described, the contour of the curve formed by the successive demand indications may be taken as an index of the load characteristics over a period of operation. When the pointer of a demand meter of the lagged type is replaced by a pen, there is obtained on the chart an actual load curve, much overdamped, so that all rapid fluctuations are smoothed out; and in many cases such a chart is found to serve a useful purpose, not only in the provision of a measure of maximum demand but as a graphic record of operation. Theoretically at least, any volt-ampere-hour meter or volt-ampere meter system which can be adapted to a device for obtaining an indication of volt-ampere demand can also be adapted to a device for obtaining a record of that magnitude. In the development of such recording volt-ampere demand meters as have been commercially produced, however, it has generally been found expedient to employ a mechanical system in which the volt-ampere value is geometrically determined from simul-

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taneous measurement of active and reactive component of the load. Two of the best-known recording volt-ampere demand meters are described in the following paragraphs.

*Westinghouse "RI" Volt-ampere Demand Meter.**

The Westinghouse recording volt-ampere demand meter, Fig. 43-39, combines the action of a watthour meter with that of a reactive volt-ampere meter to produce a deflection proportional to the volt-amperes. This is effected through the medium of an aluminum ball supported on the edges of two disks driven by the action of the respective metering elements, and driving in turn a third disk which can roll only on a great circle of the sphere. The action will be understood by reference to Fig. 43-40. Disks d_1 and d_2 are driven by a reactive meter and a watthour meter respectively. Ball C is supported upon them in such a manner that radii passing through the points of support meet at 90°. In operation the ball assumes an axis of rotation X-Y such that perpendiculars a and b are proportional to the respective speeds of the disks. It will be evident that in either of the two right triangles abc, the radius c of the

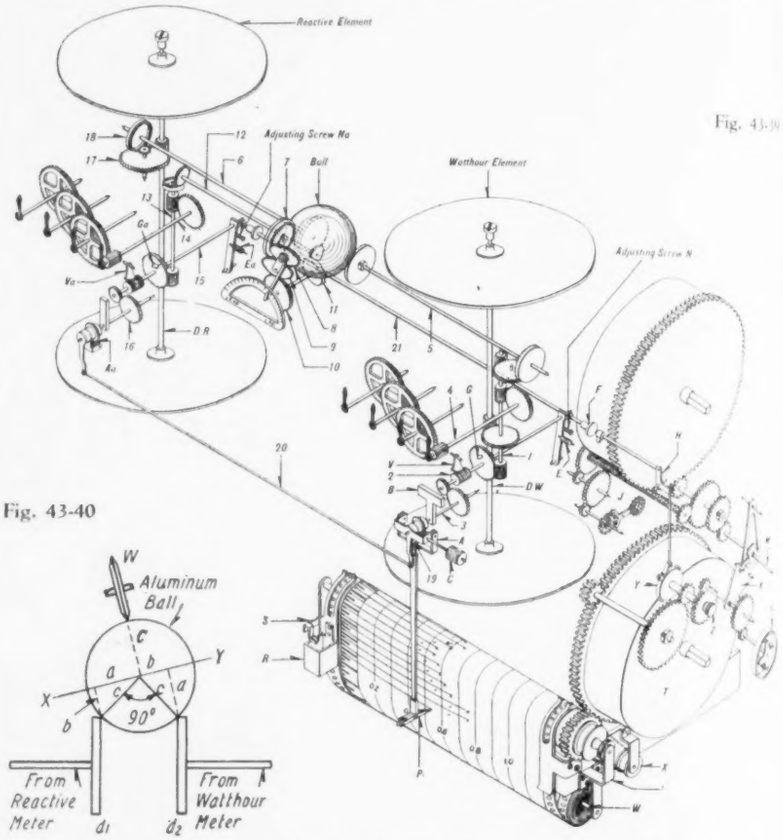

Fig. 43-39

Fig. 43-40

sphere is the hypotenuse of the triangle and therefore the vector sum of a and b. Hence the speed of rotation of the sphere about its axis will be proportional to the vector sum of the velocities, or, with the angle 90° as above, to the square root of the sum of the squares of the velocities—that is, to the volt-amperes of the load. Wheel W is mounted in a movable frame, so that it rolls on a great circle whose plane is always perpendicular to axis X-Y, and the frame is free to swing about an axis passing through the center of the ball, perpendicular to the plane in which X-Y lies. By means of gearing, wheel W drives the demand pointer of a mechanism similar to that of the "RA" meter previously described (see *Instruments*, June 1935, page 144) so that a record of volt-ampere demand on a block-interval basis is obtained. The watthour element of the meter also positions a demand element which serves as a stop for the pen; and, since the watthours can never be greater than the volt-ampere value, this stop can never be above the position of the pen. As the pen is released by the timing mechanism it falls on the stop, where it remains long enough to make a definite record, after which it drops to zero. Thus there is obtained on the one chart a record of volt-ampere and watt demand from which the power factor at any time may readily be computed. A small grad

*Smith and Rutter, *Transactions A.I.E.E.* Vol. 43, 1924, pages 297-303. B. H. Smith *Electric Journal*, March 1924, page 112.

uated dial upon which is shown the inclination of the axis of the ball provides at any time an indication of the power factor; and since the meter is also fitted with a regular watthour meter register, there is provided a mass of desirable information in regard to the load on the circuits to which it is connected.

*Sangamo Type "S" Recording Demand Meter.**

This meter is shown in Fig. 43-41; and its operation will be understood by reference to Fig. 43-42. The fundamental measurement is made by a watthour meter and a reactive meter, each of which operates a three-lead contact to the recording device. The contacts in the energy meter, through a simple motor arrangement, cause a pen to move at right angles to the travel of a strip

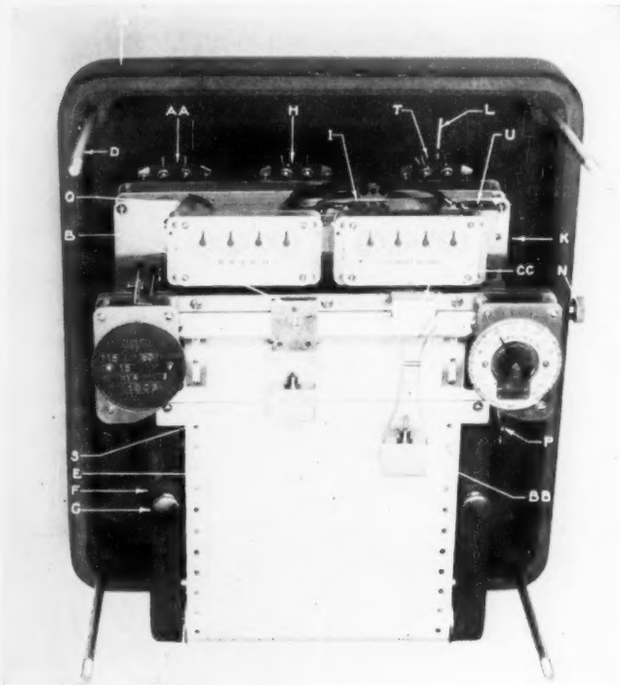

Fig. 43-41

chart, the linear motion of the chart being obtained through another motor operated by contacts in the reactive meter. This instrument is of the block-interval type, a simple timing device serving to reset the pen to zero at the end of each time interval. The pen thus draws on the chart a series of right triangles representing successive time intervals. The angle of the hypotenuse of each triangle represents the power factor for that interval, the length of

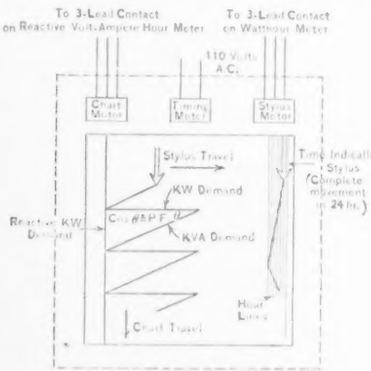

Fig. 43-42

the hypotenuse the volt-ampere demand, and the base line the kilowatt demand. On the chart a separate section with another pen operated back and forth every twenty-four hours, gives the time of occurrence of each demand by inspection of the chart. With this type of meter is furnished a chart having special graduations which facilitate the readings of the several magnitudes recorded thereon.

*U. S. Patent No. 1,790,052. Lanphier & Holtz, Jan. 27, 1931.

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is a common saying. However, to the individual brain worker, time is much more than money. *Time is life itself.* You cannot buy five more years to live.

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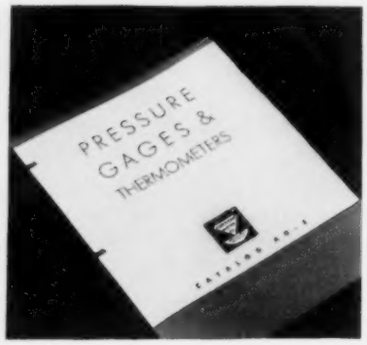

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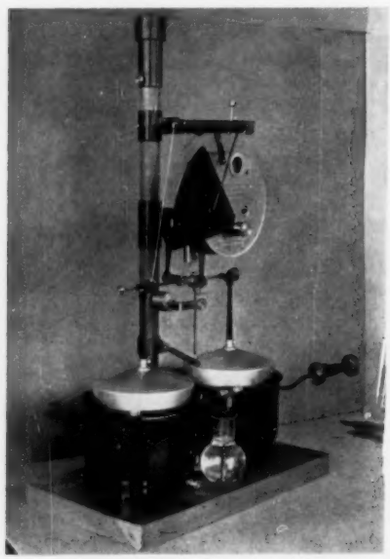

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For further information on recording volt-ampere meters (not necessarily demand meters) the reader is referred to the following published material:

H. H. Lyon, *Electrical World*, Vol. 69, 1917, page 415.
N.E.L.A. Meter Committee Report, 1917, pages 30-34.
Electrical World, Vol. 79, 1922, page 846.
U. S. Patent No. 1,619,002. G. Sperti. March 1, 1927.
W. C. Fryer. *Transactions A.I.E.E.*, Vol. 42, 1923, pages 376-380.
Canadian Patent No. 201,283, June 22, 1920.
U. S. Patent No. 1,646,634. W. F. Sutherland. Oct. 25, 1927.
U. S. Patent No. 1,651,482. W. F. Sutherland. Dec. 6, 1927.

6. Two-rate Meters

European practice has made some use of the two-rate meter, which is a watthour meter having two distinct registers, either of which may be thrown into engagement with the moving element. The throw-over is generally governed by an electromagnet, which may be controlled by an automatic time switch or by an impulse from the central station. With a meter of this type one of the registers may be arranged to read energy consumption during peak times, when the demand upon the supply system is high, and the other during those hours when excess plant capacity is available. A higher tariff on the energy registered by the former dials tends to shift the load away from the system peaks and fill up the valleys in the load curve.

7. Excess Meters

In the excess or differential meter the mechanism provides for a separate registration of all energy consumed at loads exceeding a predetermined limit. Referring to Fig. 43-44, which represents a typical load curve, the value *A* is selected as a limit to be embodied in the power contact. The total area beneath the load curve is integrated in the ordinary manner and registered on one set of

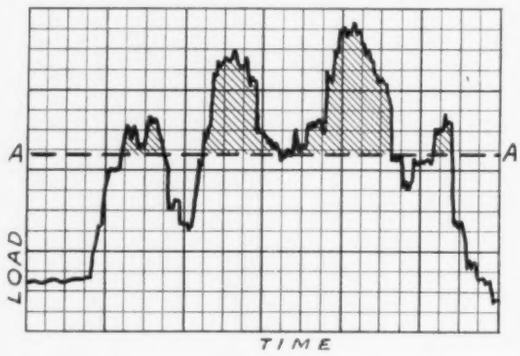


Fig. 43-44

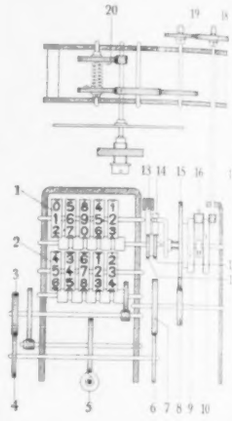


Fig. 43-45

dials, and that portion which lies above the predetermined limit (shown cross hatched in the diagram) is also registered on another set of dials. Thus it is possible to formulate a billing structure which tends to keep down load peaks by placing a surcharge on excess demands. This type of meter has not attained wide popularity in this country, but its design has reached a considerable state of refinement in Europe, and some American authorities have recommended its serious consideration.* Several different principles have been embodied in these meters, one of the best-known being exemplified in the Landis & Gyr register shown in Fig. 43-45. In this register the train 2 is driven by the watthour meter through worm 5 so that it registers the total consumption. At the same time the meter drives crown wheel 9 of the differential, through wheel train 3, 4, 6, 7, 8 and 15. The other wheel 10 of the differential is driven at a constant speed, and in the opposite direction, by clock movement 20, through pinions 17, 18 and 19. Should the consumption be less than the fixed limit, the number of turns of wheel 9 driven by the meter will be less than that of wheel 10 driven by the clock movement. Differential pinion 16 is therefore moved in the direction of rotation of wheel 10, and pawl 14, fixed to the spindle of differential pinion 16, slides over ratchet wheel 12. As a result this spindle does not transmit its movement to the spindle of the counting train 1. On the other hand, should the energy consumed exceed the fixed limit, differential pinion 16 and its spindle change their directions of rotation, so that counter 1 starts registering. It is evident that from the moment the speed of rotation of differential pinion spindle 16 equals the difference in speed between the meter and the counting train, counter 1 will record the difference between the total consumption and the fixed limit, while the total consumption will continue to be registered by train 2.

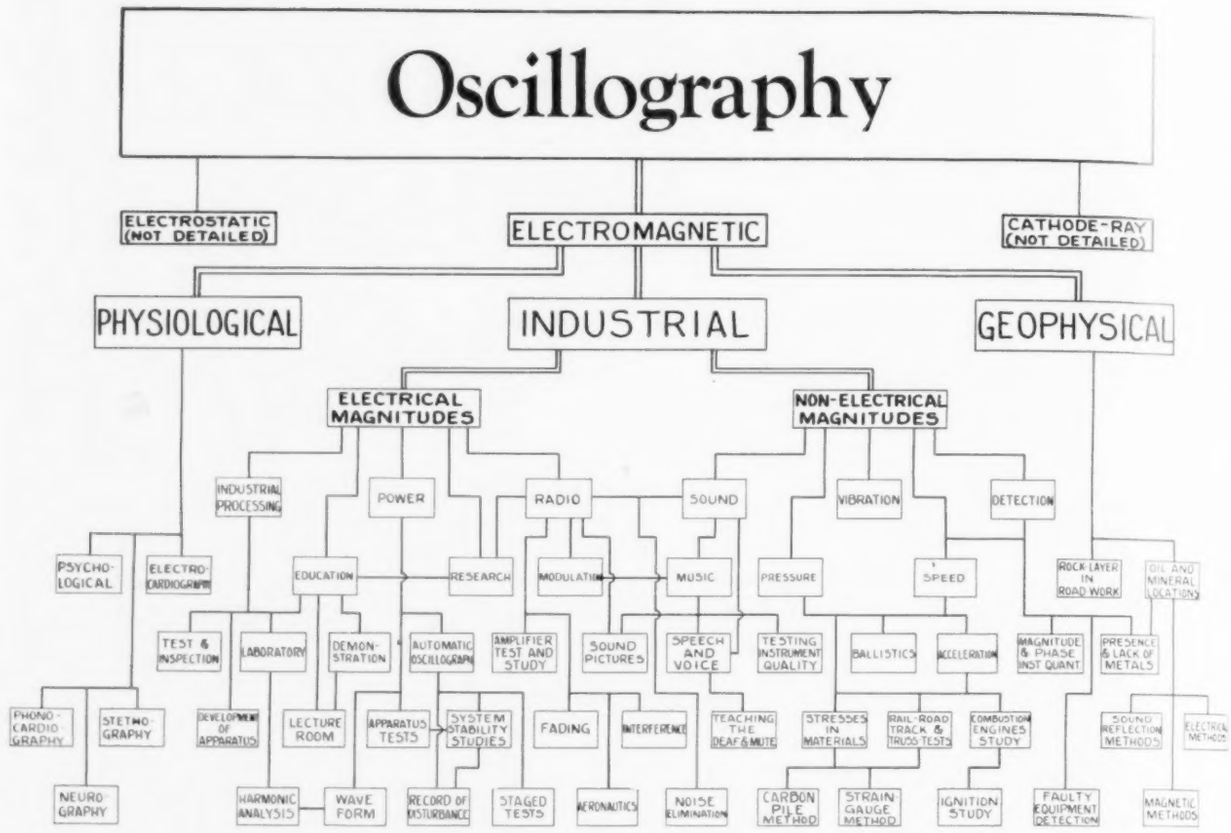
*P. M. Lincoln, *Iron & Steel Engineer*, Dec. 1934, pages 494-499.

INSPECTION and TESTING

J. HEINICKE CHECKING GAGE BLOCKS WITH AN OPTICAL FLAT

(Courtesy Bausch & Lomb Optical Co.)

The Widening Field *of* Oscillography



By VERNON S. THOMANDER* and PAUL MacGAHAN*

TO anyone who has not closely followed the development of the oscillograph as a tool of engineering, the above chart will be of interest. The oscillograph of most engineering textbooks, as originally produced by Blondel in connection with the development of generating machinery, and the later Duddell oscillograph, were complicated and cumbersome pieces of apparatus, suitable for use in scientific laboratories only. L. T. Robinson further improved the design of the Duddell type, greatly extending its usefulness as a tool of research. But it remained for J. W. Legg to invent the means for producing an oscillograph of the portable instrument type applicable, like other portable instruments, to uses outside the laboratory.

Legg's inventions, permitting the use of the incandescent lamp instead of the carbon arc and applying cobalt steel to the magnetic system of the galvanometers, revolutionized the art of oscillography. As will be noted from the chart (which was prepared especially for *Instruments* by the oscillograph development engineers of the Westinghouse Company) applications of the modern portable oscillograph extend not only through the original field of ordinary electrical magnitudes but also to radio, medicine, measurements of physical non-electrical magnitudes—depth sounding, geophysical exploration, ballistics, etc. Sounds, music, light, motion and strain are measured and studied, and even deaf-mutes are taught to speak.

To the inventor and the designer, the minute details of all motions must be mastered if development is to continue. Many of these details—mechanisms—are used because they serve the purpose and because they have been found by practice, but when their whys and wherefores are not known, these devices are sleight-of-hand performers to the designer and the researcher. To make these "monkey-motions" seen, examined and measured, the oscillograph is the instrument now generally accepted. Day by day it is raising the design limits of countless apparatus.

The oscillograph is an instrument which records so-called instantaneous or rapidly changing electrical magnitudes as a function of time. The record may be either viewed on a small screen or photographed on film or paper. The research problem then becomes a matter of transforming a mechanical motion into an electrical magnitude—which in most cases is a simple problem. In locating oil domes or rock layer, it is done by reflection of sound and picked up by microphones: the oscillograph records the change of current through the microphones. In locating various ores it is done by applying

(Continued on page 189)

*Instrument and Meter Engineering Department, Westinghouse Electric & Mfg. Co., Newark, N. J.

The Cathode-ray Oscillograph and Its Applications

By RALPH R. BATCHER

Introduction

TUBES utilizing the principles of cathode rays are among the oldest members of the electronic tube family, the effects having been discovered more than seventy-five years ago.[1] Modified types, adapted for visual delineation of electrical waves, received attention as laboratory instruments following the work of Braun in 1897.[2] Because of the remarkable results he obtained in making oscillographic studies the tubes were called Braun tubes, a name which is still sometimes used. Cathode rays are known also as electron jets, a designation that seems to have considerable merit.

Due to many recent advances in the technique of making fluorescent screens, together with improvements in focusing methods, cathode-ray tubes are becoming indispensable in many measurements. Often a single sweep of the ray over the screen is sufficient to disclose the operational characteristics of a circuit under test that would require hours of data taking and plotting if other methods were used.

This series is prepared to provide working plans for setting up such tubes and operating them and for constructing auxiliary apparatus and equipment; and to indicate methods of studying the resulting oscillograms. Examples are given of common traces which can be used in becoming familiar with such diagrams. It should be considered as a working handbook on cathode tube operation, rather than as a theoretical treatment of electronic ray projection.

A number of tubes are now commercially available both with and without the power supply. The operation of the ordinary "sealed off" type of oscillograph tube will be dealt with in particular. The operation of the high-voltage type tube within which a photographic plate is inserted in lieu of a visual screen, and which must be re-exhausted before each exposure, is highly specialized and not of general interest for ordinary testing purposes.

CATHODE RAYS

ABOUT the middle of the nineteenth century, the discovery of certain striking phenomena that result from the passage of electricity through evacuated tubes stimulated investigation by many scientists, and many new and interesting effects were produced during the next quarter-century. The familiar sparks that occur with the passage of electricity between electrodes at atmospheric pressure give way to a characteristic luminous discharge between the electrodes at even moderate degrees of exhaustion (say about 0.01 atmosphere). This discharge consists of a pink glow extending from the anode or positive terminal up to a short distance of the (unheated) negative terminal or cathode. Surrounding the cathode a violet glow is noted, the size of which depends upon the degree of exhaustion. There is, however, no intermingling of the two types of glow and a dark space is noticed between them, a characteristic first noted by Faraday.

As the degree of vacuum is increased, the negative glow increases and the positive glow recedes, the luminosity meanwhile going through several distinct changes. The first of these is that the cathode glow extends out from the cathode to such an extent that it breaks away and hovers in space unattached to either electrode. At the same time a second glowing region appears to surround the cathode. Then, as the air pressure is further reduced, the luminosity becomes less distinct and a new effect appears: At a vacuum corresponding to about a millionth of an atmosphere, all gaseous glow has practically disappeared, but the wall of the glass tube near the cathode starts to glow with a distinct color of its own, a greenish color for sodium glass or a dull blue for the harder lead glasses. This effect was termed fluorescence and was found to be due to a type of radiation from the cathode. This gave rise to the name Cathode Rays. A large number of substances were discovered that would fluoresce when subjected to this radiation.

These rays issue forth in straight lines perpendicular to the surface of the cathode. It was found that bodies placed in the direct path of this radiation became heated, and that the rays exerted a pressure upon such objects, just as if they constituted a stream of material particles.

In studying these phenomena Professor Roentgen permitted cathode rays to fall upon a heavy metal target, whereupon he found that they caused a still different type of radiation to be emitted from this target. This effect mystified scientists at first, and the secondary rays were termed X-rays. In time, however, they were thoroughly investigated, found to be electromagnetic radiation of short wave-lengths, and have since become one of the most useful types of radiation.

From the great mass of experimental and theoretical work by many investigators of cathode ray phenomena, many interesting properties were discovered. Among these it was found that the constitution of the gas mixture or the kind of pure gas remaining within the tube did not affect the main characteristics of the rays, and also that the shape and material of the electrodes had no important bearing upon the principal effects.

The most important discoveries were (1) that of Wehnelt, that the cathode gave out a greater amount of radiation if heated; and (2) that it radiated even more strongly if the heated surface was coated with certain rare earth salts.

The cathode radiation was shown to be a stream of electrically charged particles, or electrons, moving at speeds considerably slower than that of light but nevertheless faster than any other material particles. The actual speed, however, depends mainly upon the accelerating potential applied between the anode and cathode. Cathode rays *are not light waves*, as they have no wavelength of their own, and are visible only through their fluorescent action, wherein they excite electromagnetic radiation in the visible spectrum.

*Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

[1]Plucker. Fluorescence. *Poggendorff Annalen*, Vol. 103, 1858, pages 88-106.

[2]Braun. Ueber ein Verfahren zur Studium des zeitlichen Verlaufes variabler Strom. *Annalen der Physik und Chemie*. Vol. 60, 1897, pages 552-559.

A jet of water issuing from a hose would travel in a straight line if it were not affected by gravity, wind pressure, etc. In a similar way a stream of cathode rays travels in a straight line until acted on by some attractive or repulsive force. Fig. 1 shows an ordinary horseshoe magnet deflecting cathode rays. Both electrostatic and electromagnetic fields deflect the rays. Since the individual particles (electrons) are negative, they are repelled by bodies carrying the same charge and attracted

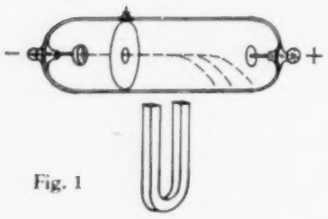


Fig. 1

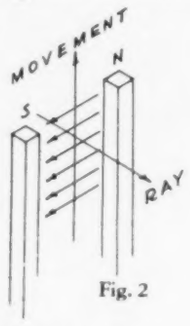


Fig. 2

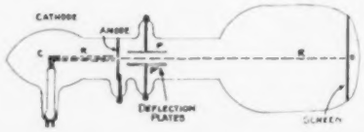


Fig. 3

by bodies carrying a positive charge. In electromagnetic fields the rays act in the same way that a wire carrying current would act, and move in the same direction (see Fig. 2). It should be remembered, however (especially when applying the Fleming left-hand rule or any other mnemonic rule), that cathode rays travel outward from the cathode, which is in the opposite direction from that usually assumed for the current in a wire.

The energy associated with cathode rays, especially when they travel at high velocities, may be made to manifest itself in various ways. Possibly the most spectacular demonstration has been the burning of diamonds, converting them into coke, and it even has been claimed that atoms can be carried along by the electron stream.[3]

High-velocity rays, of sufficient intensity to pass through thin metal or glass windows, are usually called Lenard rays, and cathode ray tubes provided with such windows Lenard tubes. Recent experiments have disclosed many new and valuable uses to which these external electron beams can be applied, some of which will be described in a later article.

CATHODE RAY TUBES

The essential parts of these tubes may be classified under four heads:

1. The source of the rays.
2. Means for focusing and modulating the stream.
3. Means for controlling or deflecting the stream.
4. A fluorescent screen.

Whatever source of rays is provided, and whatever the arrangement of the electrodes (not including the deflecting plates), the sensitivity (the amount of deflection produced per volt potential difference across a pair of deflection plates) depends upon the *speed* of the rays. This in turn is dependent upon the anode voltage, the length and the separation of the deflection plates, and their distance from the screen.

In Fig. 3 a longitudinal section of a tube is shown, in which the dotted line *R* represents a stream of cathode rays. (The actual form of the cathode *C* is immaterial for this analysis.) The stream *R* emerging from a small orifice in the anode *A* continues on and impinges on the screen *S* at some point *O*. Two deflection plates *P* and *P'* are so arranged that the stream must pass between them, but having zero potential difference between them in this diagram the spot is not deflected. The velocity of the stream is dependent upon the exciting voltage *E* (generally proportional to the square root of this voltage).

The construction of a cathode ray tube does not differ in some details from other types of electronic tubes. Disregarding for the present certain types of oscillographic tubes adapted for the study of high voltage transmission line studies, the usual envelope is made of glass. For economy and accuracy in alignment of plates it is common practice in this country to bring out as many leads as possible through the mounting stem at the base. However, for use in high-frequency circuits, connections to the deflection plates are sometimes brought out individually from the side of the tube, in order to reduce electrostatic coupling. With anode potentials higher than about 1000 volts, it may also be necessary to provide an anode lead separate from the stem. In Fig. 4 details of the elements of a typical (General Radio Co.) gas focused tube are shown. The electrodes can be made of nickel, aluminum, copper, German silver, or other materials commonly used in other types of vacuum tubes. Since the degree of vacuum is rather definitely fixed by focusing problems, it is necessary to select materials that do not adsorb or absorb gases, in order that the materials will not release gases after the tube has been manufactured. In some cases secondary emission is reduced if the anode is carbonized.[4,5] The use of German silver deflection plates has been advocated to reduce eddy currents when magnetic deflection coils are used. Fig. 5 shows a type of tube popular in Europe, the Leybold (German). American preference is for straight tubes without appendages. Actual design details will be described in a later article.

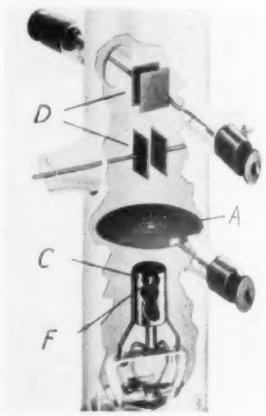


Fig. 4

CATHODE RAY TUBE CLASSIFICATION

The cathode ray principle has been utilized in many distinct types of tubes, adapted for different classes of work. A useful classification therefore is according to their uses, such as:

1. Oscillograph tubes of low or medium anode potentials, sealed off from the vacuum pump and equipped with an internal fluorescent screen.

2. Oscillograph tubes with an arrangement whereby photographic plates or films are placed inside in lieu of a screen. This type must be permanently connected to a vacuum pump.

3. High-voltage oscillograph tubes used for recording transients and rapid surges. These tubes may be equipped with either fluorescent screens or for recording diagrams on internally located photographic plates, and require anode voltages of the order of 15 to 100 kilovolts.

[3]Parsons and Campbell-Swinton. Conversion of Diamonds into Coke by Cathode Rays. *Proceedings of the Royal Society*, Vol. 80, 1907, pages 184-185.

[4]H. E. Farnsworth. Bombardment by Slow-moving Electrons. *Physical Review*, Vol. 20, 1922, pages 358-374.

[5]Farnsworth. A Method of Obtaining Intense Beams of Slow Electrons. *Journal of the Optical Society of America & Review of Scientific Instruments*, Vol. 15, 1927, pages 290-294.

4. Lenard tubes, characterized by a "window" through which the electron beam can pass. Such an external electron beam has been used for oscillograph studies, but more often they are used to supply electron beams for physical, chemical or biological applications.

5. Physical research tubes, used for the study of magnetic fields, electronic phenomena, measurement of e/m, or for classroom demonstrations.

6. Projection tubes with small screens on which the spot of light is brilliant enough to permit its projection onto large screens by means of optical lens systems.

7. Sound film recording tubes designed for use as light valves.

8. Television studio pick-up tubes, for translating moving scenes into electrical pulses to modulate the radio transmitter. Usually combine the cathode ray and photocell principles. [Television receiver tubes are usually of the same type as (1) above.]

9. Special-purpose tubes. In this group are found special designs used as frequency multipliers, electron relays, etc. In such tubes the current in the electron stream is utilized, and the usual fluorescent screen is replaced or supplemented by metallic targets or collectors.

10. "Cold-light" tubes having large fluorescent screens used as sources of light without heat.

11. Advertising display tubes wherein trade-marks, etc., are delineated on the screen in fluorescent colors.

In the following articles the oscillographic types of tubes will be taken up in detail, and further details of other types of tubes will also be given.

Fig. 5

Fig. 6

COMPARATIVE CHARACTERISTICS OF THE CATHODE RAY OSCILLOGRAPH

The cathode ray oscillograph affords advantages not possessed by other types. It usually leads the field when visual studies of a recurrent or cyclic nature are made: or when two interrelated effects in the same equipment are compared. It ordinarily costs much less than other types. It is more fool-proof in that it cannot be damaged by wrong connections to the deflection plates since there is no pointer to bend or coils to burn out. The screen of the usual tube is brilliant enough for viewing across the room in daylight, or demonstrating to a large group. Its action is instantaneous and high-speed effects can be studied without distortion. Records can be made photographically either of the individual figures, or of continuously changing phenomena on a moving film. In the latter case the results are comparable with those of other oscillographs if the anode voltage is increased somewhat over that necessary to give adequate visual indications.

On the other hand the cathode ray oscillograph has limitations which are disadvantageous when certain classes of work have to be done. Chief among these limitations is the lack of permanent calibration, since the position of the spot and the extent of the deflection are affected by changes in the applied voltage to the electrodes, and to some extent by stray fields in the vicinity of the tube. Another inherent limitation of the cathode ray type, that of having but a single indicator or element, can be overcome in some instances by circuit provisions. Still another limitation is the dimensional limitation of the screen, but the other types of oscillographs all have a corresponding limitation.

ESSENTIAL EQUIPMENT

What equipment comprises a cathode ray oscillograph? Beside the tube, as heretofore described, it is necessary first of all to provide a plurality of voltages to operate it. These are usually (and conveniently and cheaply) obtained from a power supply device connected to the power mains, which device embodies controls for focusing and brilliance adjustments. With this, we are enabled to operate the tube and are rewarded with a spot of light on the screen. Fig. 6 shows a typical combination of tube and power device (as built by the author).

In order to obtain useful information, however, it is necessary to deflect the ray in accordance with some definite function of the problem under investigation. In many cases voltages and or current waves are available from the circuit or equipment under test, so that the cathode ray tube deflection circuits can be connected as are instruments. In this case the spot of light on the fluorescent screen will follow functional variations automatically and no other equipment is required.

In other tests it may be necessary to deflect the beam along one axis in proportion to time, or to rotate it in a circle or back and forth at a definite rate. Here some type of sweep circuit is necessary.

Finally, in order to convert non-electrical conditions, such as speed, pressure, stresses, vibration, etc., into the electrical pulses necessary to produce the deflection, additional equipment is required.

All of these equipment items will be described in detail in subsequent articles, together with development applications and methods for interpreting and analyzing the oscillograms.

THE WIDENING FIELD OF OSCILLOGRAPHY

(Continued from page 186)

a potential of a known voltage and frequency between two distant points on the earth's surface and picking up potential drops of this frequency with regularly-spaced electrodes at as many locations as necessary between these two distant points. In determining the instantaneous or varying loadings in any constructional member it is done by using a strain-gage which changes the micromotions to a corresponding changing current. The electrical potential produced by action of the heart, the motion of a muscle, or the travel of a thought in the nervous system, is picked up and recorded by the oscillograph.

This instrument has become useful for all manner of sequence and timing studies, as in engine design for the determination of the pressure or work cycle and for ignition and timing study; also in radio, particularly for modulation study, and in the musical conservatory for the study of the quality of the human voice. It is applicable in the educational field to exhibit instantaneous variables in the class or lecture room.

Oscillographs are now designed to work automatically and are placed out at remote points, waiting sometimes for weeks ready to start any moment—and to get under way as quickly as in 1/120 of a second—to record lightning strokes and their effects on electrical power transmission lines.

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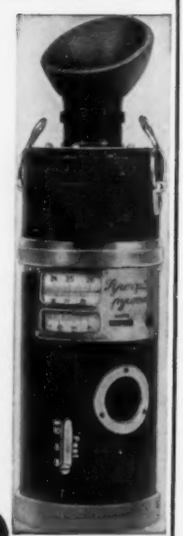

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In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

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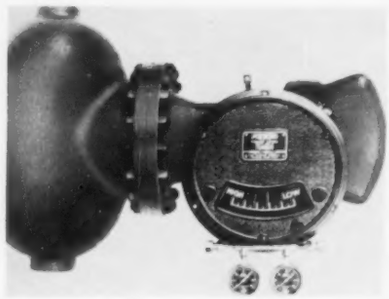
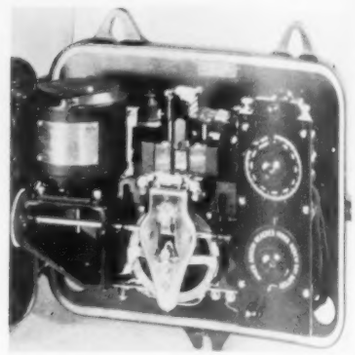


Liquid Level "Stabilog"

The Foxboro Co. announces a new type of liquid level control instrument: its "Stabilog" system of control added to a ball float mechanism, the combination designed to maintain level within safe limits and to give a smooth out-flow without creating upsetting surges. Sudden increases in input that would ordinarily cause such surges are said to be averaged out by the Stabilog. The novel ball float mechanism, said to be the result of over four years of research by Foxboro engineers, employs a knife edge bearing which was found to be the nearest approach to a frictionless bearing for this work. The steel ball float is counterbalanced by movable weights to assure maximum accuracy. It is said that this new controller can easily be adapted to any type of installation. It may be installed with the ball float inside the pressure vessel, or on the outside with a kidney type float chamber.

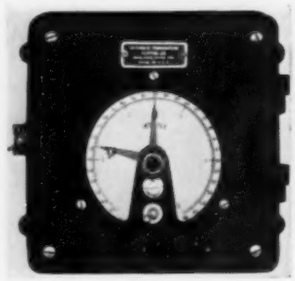


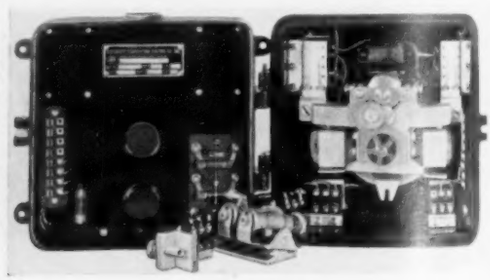
Self-balancing Controller

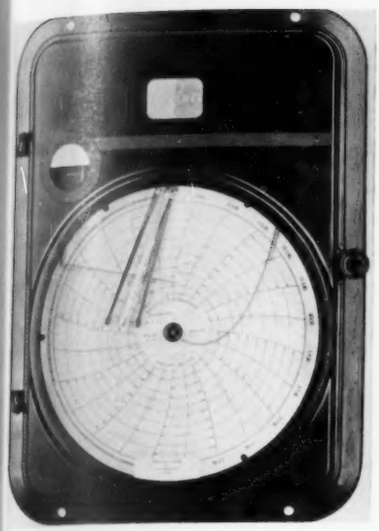
Designed for severe service in steel, ceramic, glass and chemical plants, the new Micromax Two-position Controller announced by Leeds & Northrup is a "Micromax" null-method system of rugged construction, housed in a single case and stripped to essentials: no recording or indicating elements. Its operating function, performed by a single or double-throw mercury switch, is to open or close one or two circuits as the e.m.f. or resistance of the measuring circuit departs from the setting point. The measuring circuit may be a potentiometer or wheatstone bridge, so that this new instrument, although primarily designed for temperature control, may be employed for regulating other conditions, chemical properties, etc. All setting dials are individually calibrated.

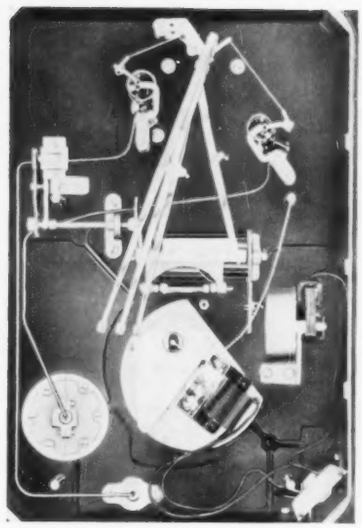
Adjustable-sequence Repeat Controller

The Automatic Temperature Control Co. announces the new "Series 1274-5-6 Time Controls," designed to repeat one or two operations or processes as often as desired. Provision has been made for exceedingly flexible choice of periods during which the controlled actions take place, it being said that the new controllers will handle a repetitive action or operation requiring a definite time period or cycle with either the same or different time period between successive time cycles. The time cycle and also the interval between successive cycles is infinitely adjustable with an accuracy of setting to well within a scale division of the respective dial ranges selected. Parts have been so grouped on chassis that adjustment is simple. Jack connections permit removal of parts without disturbing wiring. Settings are said to remain accurate despite vibration, and "special contact-metal transmits current even when oxidized."









Flow Meter

Employing the orifice (or Venturi) and mercury manometer system of flow measurement, the new instrument announced by The Bristol Co. is claimed to meet the needs of industry for a rugged and accurate mechanical flow meter designed for severe field conditions. The meter body is of forged steel with mercury chambers of uniform cross-section areas, said to contribute to accuracy and interchangeability and such that small changes in mercury volume incidental to capillarity and adhesion do not impair accuracy. A long float lever arm connects a large float to the pen arm, assuring, it is said, sensitivity without jumping and sustained accuracy. Connections are welded or mechanical. Parts are counter-balanced. Working parts can be cleaned without disturbing calibration. A hardened stainless steel stuffing box lapped to the shaft is grease-packed and said to be leak-tight. Range-changing is effected by changing either the orifice size, the manometer high-pressure leg, or both. The integrator, positive in action, has no friction contacts or friction clutches. Gravity-operated check valves prevent mercury blow-over. Meters for working pressures of 1000 lbs. are tested at 2000 lbs. Special bodies tested at 5000 lbs. are obtainable for working pressures up to 3000 lbs. The new meters are available as indicators, integrators, recorders or controllers. Recorders can be furnished with pressure and temperature elements (as illustrated). Integrating flow meters are obtainable with or without automatic compensation for static line pressure fluctuations. When combined with the Bristol "Metameter," this new instrument constitutes a remote-reading electric flowmeter.

Direct-reading Anemometer

Instantaneous indications of the speed and direction of air currents are given by the "Boyle Velometer," a readily portable instrument brought out in two types by Illinois Testing Laboratories, Inc. The

shutter type (illustrated) is so called by reason of a rotary shutter employed to open and close ports to change the scale range. In use it is held with the ports perpendicular to the air stream. The *tube type* has an attachment with 30" flexible tube and jet used for high-range readings. Various forms of jets are available, each designed for a specific function, as for grilles, ducts, leaks, suction, etc. *Principle*: the air passing through the instrument tilts a vane provided with restraining spring and damping system. *Features* include zero adjuster and pointer clamp.

Current-testing Set

A portable "Novalux" current-testing set for checking the current in series lighting circuits has been developed by the General Electric Co. to assist in maintaining the rated light output and the rated life of series lamps. Intended primarily for use on automatically operated constant-current transformer circuits where an ammeter is not available, it consists of an ammeter having both a 12.5-amp. and a 25-amp. scale; a current transformer of 25-amp. capacity having a 1:1 ratio; 25 ft. of cable ending in a standard series socket (with disk cut-out) for plugging into a recommended weatherproof aerial-type receptacle; an oak box housing the component parts; and a leather carrying case for the ammeter.

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MODEL CRA Cathode-Ray Oscillograph illustrated above contains standard 3-inch tube, power supply, linear sweep circuit, and input amplifiers, in one compact unit. Write for full details.

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Dynamometer wattmeters, milliammeters and voltmeters. Also ultra-sensitive meters both for A.C. and D.C., fluxmeters, electrostatic voltmeters from full scale 120 volts to over 20,000 volts, thermocouples, earth current meters, cable testers, fluxmeters, etc.

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Kilovoltmeter Multipliers

The Shallcross Mfg. Co. announces a line of resistance boxes designed to furnish practical and inexpensive external multipliers for a wide variety of standard instruments for measuring potentials up to 25,000 volts a.c. or d.c. They are classified according to resistance, voltage and current. For example any 0-1 d.c. milliammeter can be associated with the "Type 720" Multiplier for voltage ranges of 1, 2, 5, 10 and 20 kv. This combination is, therefore, a 1000 ohms-per-volt multi-range kilovoltmeter. If it is desired to have a lower current drain from the system any 0-100 microammeter associated with a Type 720 multiplier, provides voltage ranges of 100, 200, 500, 1000 and 2000 volts having resistance of 10,000 ohms per volt. For accurate a.c. measurements, the makers recommend the use of a one-milliampere thermocouple associated with any d.c. 0-5 millivoltmeter and the "Type 725" multiplier to cover ranges up to 25 kv. These new devices are easily adapted for use as resistance standards, particularly those multipliers for use with low-current instruments requiring relatively high resistance. They can be furnished with additional binding posts so that all or part of the resistance can be employed. The Shallcross Multipliers can also be supplied with a small 3½" instrument mounted on the panel. These instruments have an accuracy of 2% d.c. and 5% a.c. if the wave form is roughly sinusoidal.

Carbon Resistors

The operation of electronic selective and control apparatus, such as alarms, counters, etc., being in many cases improved by the introduction of low-resistance units in the circuit, thus producing a more uniform sensitivity curve, the Ohio Carbon Co. is introducing a new type of low value resistors (known as the "LV" series), using carbon —the non-inductive properties of which give it advantages over wire-wound low-resistance units. Values as low as 0.04 ohm, in capacities from one-quarter watt to 10 watts, are available. These new low-value carbon resistors compare as to their load, voltage, life, overload and humidity characteristics with the Company's line of "Ohiohm" resistors of higher ohmic values. It is stated that even under humidity conditions approximating those of a tropical rainy season they will function satisfactorily.

BOYLE VELOMETER
Instantaneous Direct Reading Air Velocity Meter
20-feet to 6000-feet per minute
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Thermocouple Lead

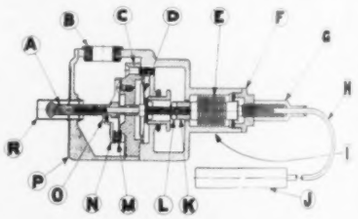
Only the part which is actually burned out needs to be purchased by the user of an ingenious universal thermocouple mounting brought out by the Claud S. Gordon Co. As a rule, it is said, only the new wires need be ordered at no more cost than the average repair job. The cap and base are of cadmium-plated malleable iron; the connector block is heat-resisting and unusually strong; the heat- and moisture-proof gasket is fitted to a machined surface; the whole is made in two models, to fit all standard thermocouples.

Recorder for Continuous Wire Gage

The Federal Products Corp. announces that its Model 493 continuous wire gage may now have attached thereto a round-chart recorder made by The Foxboro Co. The combination serves to check each run of wire, not only recording its diameter but showing the number of breaks and the time consumed in repairing them.

Gas Safety Switch

The Spencer Thermostat Co. announces for electrically controlled gas-fired furnaces and heaters the Klixon Type C-1888 Pilot Safety Switch, claimed to be positive protection against the escape of unburned gas in the case of pilot extinguishment. Special changes in the furnace of heater with which it is to be used are unnecessary. Mechanical installation difficulties are said to have been eliminated, as the capillary may readily be bent to place the bulb over



the pilot flame. This device consists essentially of a bellows operated by a bulb, the assembly filled with inert gas under pressure and expanding when the bulb is heated by a pilot flame to exert pressure against the Klixon disk and switch assembly. The switch must be closed manually. Upon extinguishment of the pilot the disk operates to open the contacts of the switch assembly and by so doing the electric valve is closed and shuts off the gas supply. This device is designed to provide safe operation of the gas appliance when used in conjunction with an automatic gas valve which may or may not be thermostatically operated. It is rated at ¼ h.p., 110 volts a.c., 5 amps. or 2.3 amps. at 110 volts d.c.

Orifice Fittings

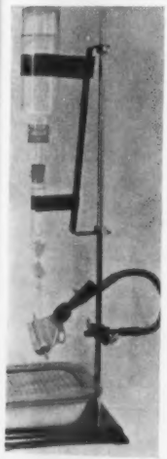
Announcement has been received of the appointment of The Foxboro Co. as sole distributors of "Commercial" Orifice Fittings, made by the Commercial Iron Works. These devices eliminate the nuisance and expense of by-passes, and save space. The threaded elevator lift permits lowering or lifting of orifice plates regardless of line pressure, without shutting down the line and with complete safety to the operator. Additional features are accurate centering of orifice plates and elimination of set screws in pressure areas.

Pasteurizer Thermometers

A new line of "American" pasteurizer thermometers announced by the Consolidated Ashcroft Hancock Co. is characterized by the "new universal scale covering the entire range of dairy uses from 30 to 220°F." Scale plates are silver finish with black and red graduations: pasteurizing range in red with 1° divisions $\frac{1}{16}$" apart. Tubes bear red etched lines at 143 and 145°F. or at any other points required by local ordinances. Tubing is of red reflecting construction which shows the mercury column as a red stripe. Stems are of 18-8 stainless steel; frames are chromium-plated; cases are frosted nickel. All standard straight and angle forms are available.

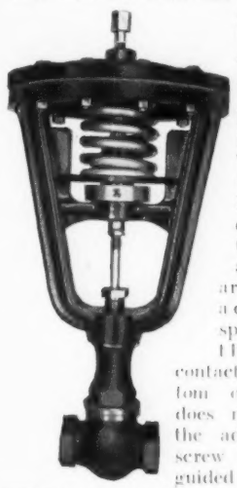
Cadmium and Zinc Coating Tester

The Plating Products Co. announces the "Chemicrometer," an apparatus for determining the thickness of electroplated cadmium or zinc coatings by making use of a "dropping" method said to have been recently checked at the National Bureau of Standards. A corrosive solution is allowed to fall at a constant rate on the plated article, which is so held that the dropping stream strikes the point to be tested. The coating is dissolved at a uniform rate which, for zinc and cadmium, is taken as 0.00001" per second. The time from the beginning of the test to the end point (plating completely dissolved) is a measure of the thickness. The solution is contained in a reservoir bottle from which it is fed to a two-stop-cock funnel. One stop-cock is for full-off or full-on; the other is set to give the desired rate of flow and need not be disturbed when once set. The solution in the funnel remains at the same level, regardless of the amount in the reservoir bottle, so that a constant head is maintained. The method is rapid (approx. 1 min. for ordinary zinc or cadmium deposits) and also of advantage in that any suspected or vulnerable spots in the deposit can be measured independently of the surrounding coating. Thus, areas which have been known to break down in service can be tested directly. The article under test is not destroyed and can be replated for shipment.



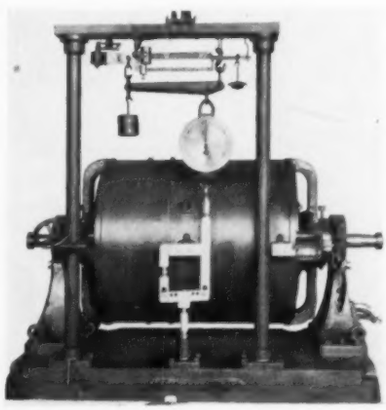
Control Valves

Appreciation of the importance of the valve as the business end of any control system and the need of matching the valve with the controller in performance characteristics, has led the C. J. Tagliabue Mfg. Co. to develop a new long-range throttling top. This construction is said to incorporate several new features of design, among them the arrangement for adjusting the spring pressure: the member in contact with the bottom of the spring does not turn when the adjusting feed screw is turned but guided by the two vertical fins of the spider arms merely moves up or down. Thus spring adjustment does not tend to wind up the spring or disturb its normal characteristic. The new long-range throttling top is available at this date in three sizes: $7\frac{1}{2}$", $9\frac{5}{8}$" and $11\frac{3}{4}$" overall diameter. Illustration shows a globe valve with the new top.



High-Speed Dynamometers

Maximum speeds up to 6,000 r.p.m. are attained in electric dynamometers of 100 and 200 h.p. ratings announced by the General Electric Co., by reason of improvements in the bearings, lubricating systems, and electrical design of d.-c. machines. (Previously, 5,000 r.p.m. was considered the maximum for such capacities.) The new G-E machines are available either with beam-and-dial scale equipment (as illustrated) or with Toledo, Kron, or Howe Weightograph automatic scales.



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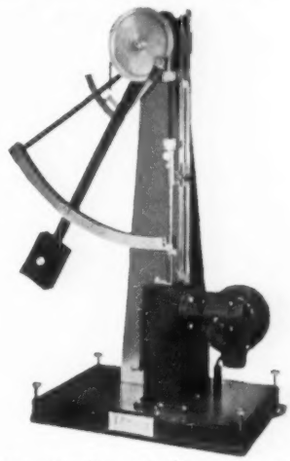

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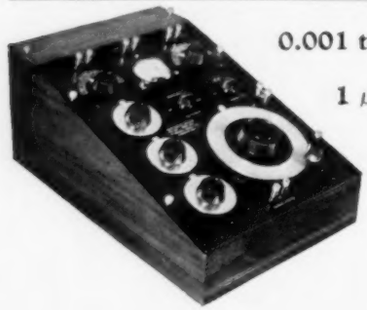

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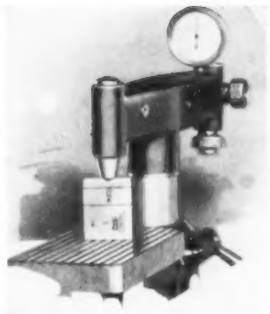

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MICROCINEMATOGRAPHY

(Continued from page 169)

filter used, the adjustment of the substage condenser, the density of the object, etc.

It now seems obvious that a microcinema apparatus, as used in a modern laboratory, cannot possibly be very simple and the Standard Microcinema Apparatus, which will now be described, is the result of a rather slow process of development based upon many years of laboratory work with a great variety of material.

The Standard Microcinema Apparatus

This apparatus, Fig. 4, was designed with the object of making its operation as simple as possible, without sacrificing accuracy and workmanship and without making it expensive. Its adjustments, many of which are automatic, permit the operator to give his attention to the object rather than to photography, so that it can be operated by anyone with some training in microscopy. It consists mainly of four separate units:

(A) *The Optical Bench*, carrying the microscope which stands on an adjustable platform, the light source (interchangeable) a system of condensers, cooling cells and light filters. For temperatures required in medical, bacteriological, chemical and other such work, an incubator (E) can enclose the microscope.

(B) *The Camera Support*, consisting of a heavy iron stand with a movable stage which can be raised and lowered by an electric motor. Limit switches, such as used on elevators, prevent accidental crushing of the microscope should the stage run down too far. A focusing device can be brought in line with the optical axis of the microscope by shifting the camera to the side. This enables one to obtain a focus of critical sharpness upon the plane of the photographic emulsion. This is especially important when high magnifications are employed. There is also an observation tube of the "beam splitter type" which permits observation during exposure, although its use has its limitations. Other parts on the camera support are the camera driving mechanism, an image counter and a relay for intermittent operation.

(C) *The Two Motors.* One drives the pulley of the driving mechanism directly while the other has reduction gears. Both units are placed at equal distances from the pulley so that the belt can be shifted in a few seconds. The direct motor has an adjustable speed governor, while the reduced-speed motor has a magnetic brake, necessary for stop-motion work.

(D) *The Control Panel.* All electrical connections are controlled from this panel. There are a voltmeter and an ammeter, dials for setting time intervals for stop motion work (images per hour and images per minute), motor control switches, outlets for a.c. and d.c., special outlets with resistors for arc lamps for 10, 20 and 30 amps. Two timing devices with synchronous motors are directly below the panel. The main switch on the panel can be operated by hand and also automatically. This permits one to start and stop the apparatus automatically at any predetermined time within 12 hours. A table indicates the various settings possible with this apparatus (1 image per hour to 32 images per second) and helps also to eliminate all calculations with respect to length of film, number of images, period of action, period of projection, acceleration, etc.

Intermittent operation, possible with this apparatus, offers advantages over continuously driven apparatus. To change speed (for instance from 1 to 8 images per minute) one has only to set the dial on the panel. The length of exposure and the light intensity will remain the same. A change of this sort on a continuously-driven apparatus would necessitate a number of adjustments on motor, illumination, microscope condenser, etc., and also experiments as to correct exposure (developing and fixing of film strips) and so causes a waste of time and material.

In order to eliminate the transmission of vibrations (which of course are also magnified with the object) the Standard Microcinema Apparatus is divided into separate units with no rigid connections between them. In addition, vibration absorbers are placed under the legs of the optical bench and of the camera support, making these units "floating."

Microcinema Outfit for 16 mm. Cameras.

Demand for a microcinema apparatus using 16-mm. amateur cameras led the author to design an equipment which, although simple in construction, can be used not only for microcinema work but also wherever vertical motion pictures have to be taken, utilizing the advantages of the focusing device which is part of the equipment. The apparatus has already many uses in its simplest form. A number of attachments can be added from time to time whenever such are required, for instance, an observation tube (beam splitter), a macro camera attachment, a portable timing device, a control panel, an optical bench, etc.

The microscope is ordinarily placed upon the base plate of the apparatus between metal strips for proper alignment, but can also be set on a separate table to eliminate the transmission of vibrations if these should be present. For this purpose the upper part of the stand, carrying the camera and focusing device can be turned 180°, as in Fig. 5 which shows the outfit when it is used for photographing small objects such as insects. Fig. 6 represents a more complete set up in combination with timing device for stop-motion work. This device has incorporated many of the features described in connection with the Standard Microcinema Apparatus.

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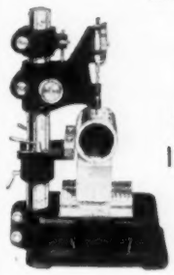

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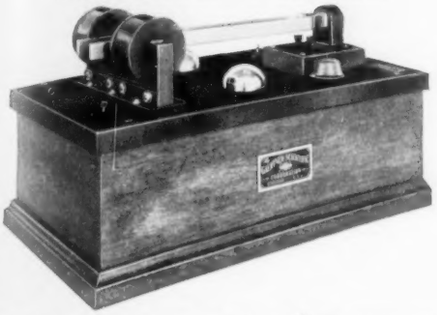

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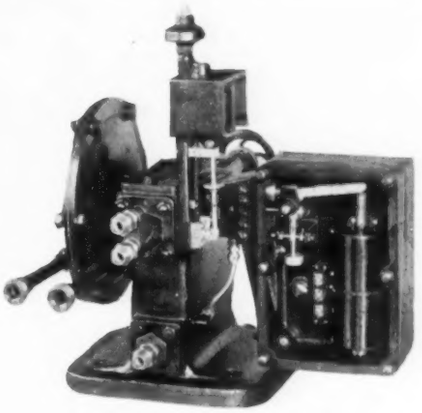

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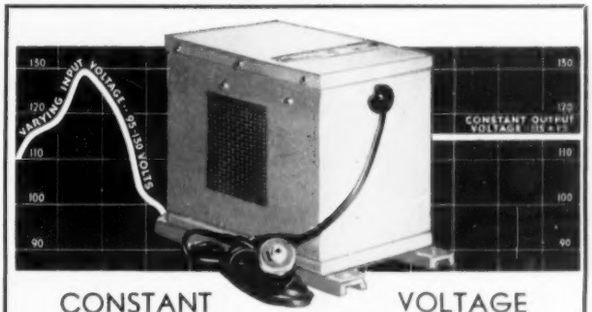

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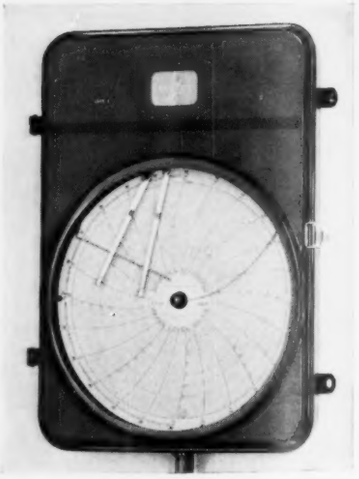

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